# Chapter 22

# Rigging Operations

## Topics

1.0.0 Basic Engineering Principles

2.0.0 NAVFAC P-307

3.0.0 Wire Rope

4.0.0 Fiber Rope

5.0.0 Chains

6.0.0 Slings

7.0.0 Mechanical Advantage

8.0.0 Safe Rigging Operations

*To hear audio, click on the box.*

## Overview

Rigging is one of the most important safety and risk exposure considerations on any construction project. It is one of the techniques used in handling equipment and is used to handle a wide range of material using weight handling equipment (WHE). This equipment includes wire rope, fiber rope, chains, and slings. Rigging operations are a vital part of your job as a Equipment Operator (EO).

The Naval Construction Force (NCF) requires an in-depth program for maintenance and use of all rigging gear to ensure that all weight-handling operations are performed safely and professionally.

This chapter will cover the mechanical advantages of safe rigging operations and characteristics.

## Objectives

When you have completed this chapter, you will be able to:

1. Understand basic engineering principles associated with rigging operations.
2. Describe the purpose and contents of NAVFAC P-307.
3. Identify the characteristics, maintenance, and attachments of wire rope.
4. Identify types, handling, and inspection of fiber line.
5. Understand chain grades, strength, and maintenance.
6. Identify the types and uses of slings.
7. Identify types and use of mechanical advantages.
8. Understand how to perform rigging operations.

9. Understand rigging safety.

## Prerequisites

None

This course map shows all of the chapters in Equipment Operator Basic. The suggested training order begins at the bottom and proceeds up. Skill levels increase as you advance on the course map.

| | | |
|---|---|---|
| Miscellaneous Equipment | ↑ | E Q U I P M E N T |
| Paving Operations and Equipment | | |
| Rigging Operations | | |
| Cranes | | |
| Rollers | | |
| Dozers | | |
| Scrapers | | |
| Graders | | |
| Ditchers | | |
| Excavators | | |
| Backhoe Loaders | | O P E R A T O R |
| Front-End Loaders | | |
| Rough Terrain Forklifts | | |
| Truck Driving Safety | | |
| Truck-Tractors and Trailers | | |
| Tank Trucks | | |
| Dump Trucks | | |
| Medium Tactical Vehicle Replacements | | |
| Earthwork Operations | | |
| Electrical and Hydraulic Systems | | B A S I C |
| Chassis Systems | | |
| Power Train | | |
| Engine Systems | | |
| Transportation Operations | | |

## Features of this Manual

This manual has several features which make it easy to use online.

- Figure and table numbers in the text are italicized. The Figure or table is either next to or below the text that refers to it.
- The first time a glossary term appears in the text, it is bold and italicized. When your cursor crosses over that word or phrase, a popup box displays with the appropriate definition.
- Audio and video clips are included in the text, with italicized instructions telling you where to click to activate it.
- Review questions that apply to a section are listed under the Test Your Knowledge banner at the end of the section. Select the answer you choose. If the answer is correct, you will be taken to the next section heading. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.
- Review questions are included at the end of this chapter. Select the answer you choose. If the answer is correct, you will be taken to the next question. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

# 1.0.0 BASIC ENGINEERING PRINCIPLES

For any rigging operation, the first order of business is to determine forces (loads) and their direction, magnitude, load-bearing surfaces, method of connection, required support, and effects of motion. After determining these factors, select equipment for safe handling and installation of the load.

To determine the above factors, the rigger must know something about fundamental engineering principles such as determination of sling angle stress, load weight, weight distribution, center of gravity, and D/d ratio.

## 1.1.0 Load Weight Determination

Determination of load weight will provide you the capacity of gear and the crane. Remember, you must know the weight to prevent overloads. You must know the load weight and what load weight will excedd 50% of the crane's hook capacity.

### 1.1.1 Methods of Determining Load Weight

The following is a list of acceptable methods used for determining load weight:

- Load indicating device
- Label plates
- Documentation
- Engineer evaluation
- Approved calculations

**NOTE**: NEVER take word of mouth weight estimations to establish load weight.

The following is a list of basic rules to be followed when calculating weights:

- Round up on all dimensions
- Never mix feet and inches
- Round up on calculated weights
- Always double check your weight estimates

### 1.1.2 Using Area to Calculate Weights

The value of area for any given object can be used to calculate weights. Multiply square feet by material weight per square foot based on a specified thickness. In order to do this, you must first calculate the area of a given object.

### 1.1.2.1 Area of Rectangle or Square

Formula:

A = L x W (Rectangle) or A = B x H (Square). Refer to *Figure 22-1*.

A = Area

L = Length

W= Width

B = Base

H = Height

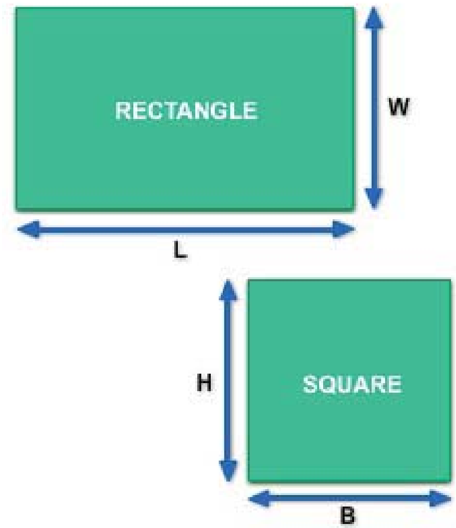



**Figure 22-1 — Area of rectangle and square.**

### 1.1.2.2 Area of a Triangle

Formula:

A = $\frac{B \, x \, H}{2}$

A = Area

B = Base

H = Height

Refer to *Figure 22-2*.

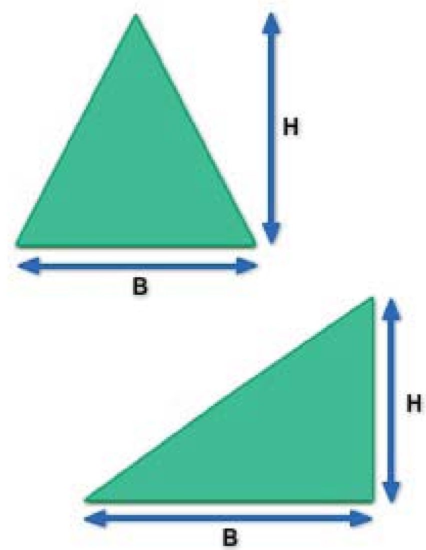



**Figure 22-2 — Area of a triangle.**

### 1.1.2.3 Area of a Circle

Formula:

A= $\pi \, x \, R^2$

A = Area

$\pi$ = 3.14

R = Radius

Refer to *Figure 22-3*.

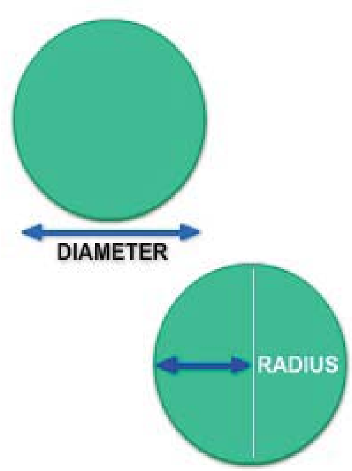



**Figure 22-3 — Area of a circle.**

### 1.1.2.4 Area of Complex Shapes

When encountering complex shapes, the first thing to do is to split the shapes into more common shapes (See *Figure 22-4*). In this case, the complex shape is split into a square and triangular shape.

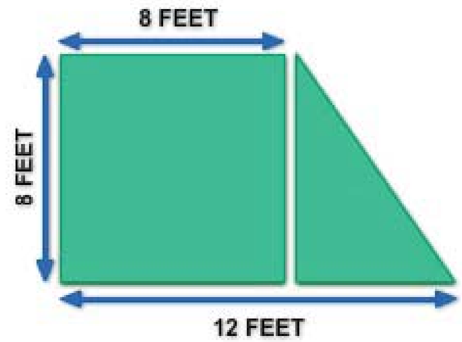



**Figure 22-4 — Complex shape breakdown.**

The first step is to figure out the area of the square shape, using the formula previously discussed.

A = B x H

A = 8 x 8

A = 64 square feet (ft$^2$)

Now, calculate the area of the triangle, using formula previously discussed.

$$A = \frac{B\,x\,H}{2}$$

$$A = \frac{4 \text{x} 8}{2}$$

$$A = \frac{32}{2}$$

A = 16 ft$^2$

Finally, add the area of the square and triangle together to get the total area of the complex shape.

A = 64 + 16

A = 80 ft$^2$

### 1.1.2.5 Calculating Weight Using the Area of Complex Shapes

Let us continue with the example demonstrated above. We know that the total area of this complex shape is 80 ft$^2$, and the object is manufactured out of steel. The next step in determining load weight is to obtain the thickness of the shape. Determine this by using any standard distance measuring device (i.e. ruler, measuring tape, or laser). In this case the thickness is 1 inch. Since you know the material is manufactured out of 1 inch thick steel, reference *Table 2-1* to determine weight per square foot of material. In this case, the weight is 40.8 lbs/ft$^2$, but remember the basic rule to round up, so the answer is 41 lbs/ft$^2$.

**Table 22-1 — Material Weights.**

| Material | Weight per cubic foot | Material | Weight per square foot per inch of thickness |
|---|---|---|---|
| Pine (white) | 25 | Aluminum | 14.5 |
| Fir | 34 | Zinc | 36.7 |
| Oak | 50 | Tin (cast) | 38.3 |
| Maple | 53 | Steel | 40.8 |
| Water (salt) | 64 | Stainless Steel | 41.7 |
| Sand (dry) | 105 | Brass/Nickel | 44.8 |
| Reinforced Concrete | 150 | Monel/Copper/ Phosphor/Bronze | 46.4 |
| Aluminum | 165 | Silver | 54.7 |
| Zinc | 440 | Lead | 59.2 |
| Steel | 490 | | |
| Stainless Steel | 500 | | |
| Brass/Nickel | 537 | | |
| Monel/Copper/ Phosphor/Bronze | 556 | | |
| Lead | 710 | | |
| Plutonium | 1211 | | |

Now you have all the values needed to calculate the load weight. Use the following formula: W = A x MW

W = Weight

A = Area

MW = Material Weight

W = A x MW

W = 80 $ft^2$ x 41 $lbs/ft^2$

W = 3,280 pounds

### 1.1.2.6 Calculating Weight Using Area of Triangle

First, calculate the area of the triangle.

Given:

Base = 12 feet　　Material: Brass

Height = 5 feet　　Thickness: 3 inches

Solution:

$$A = \frac{B \, x \, H}{2}$$

$$A = \frac{12 x 5}{2}$$

A = 30 $ft^2$

Now refer to *Table 2-1* to determine weight per square foot for brass. In this case you find a value of 44.8 lbs; after rounding up, the true value is 45 lbs/ft$^2$. Since the material is 3 inches thick, we must multiply the weight by 3.

3 x 45 lbs/ft$^2$ = 135 lbs/ft$^2$

Now calculate the weight of the object.

W = A x MW

W = 30 ft$^2$ x 135 lbs/ft$^2$

W = 4,050 pounds

#### 1.1.2.7 Calculating Weight Using Area of an Circle

First, calculate the area of the circle.

Given:

Radius = 2 feet Material: Steel

Thickness: 1 1/2 inches

Solution:

A= $\pi \, x \, R^2$

A = 3.14 x 2 x 2

A = 12.56 ft$^2$; after rounding up you get 13 ft$^2$.

Now refer to *Table 2-1* to determine weight per square foot for steel. In this case you find a value of 40.8 lbs; after rounding up, the true value is 41 lbs/ft$^2$. Since the material is 1 1/2 inches thick, multiply the weight by 1.5.

1.5 x 41 lbs/ft$^2$ = 61.5 lbs/ft$^2$; after rounding up you get 62 lbs/ft$^2$.

Now calculate the weight of the object.

W = A x MW

W = 13 ft$^2$ x 62 lbs/ft$^2$

W = 806 pounds

### 1.1.3 Volume Calculatons

#### 1.1.3.1 Volume of Cubes and Rectangular Prisms

Formula: V = L x W x H

V = Volume L = Length

W = Width H = Height

Now lets try an example of volume calaculation for a rectangular prism. Refer to *Figure 22-5.*


**Figure 22-5 — Volume of rectangular prism.**

Given:

Length = 10 feet     Width = 4 feet     Height = 2 feet

V = L x W x H

V = 10 x 4 x 2

V = 80 cubic feet ($ft^3$)

Now calculate load weight for this object. Refer to *Table 2-1* for material weight. Be sure to reference the correct column; remember this is volume, which is in cubic feet. The material weight for fir material is 34 $lbs/ft^3$. Now calculate the load weight. Note the formula for load weight now reflects volume in cubic feet.

W = V x MW

W = 80 $ft^3$ x 34 lbs/ $ft^3$

W = 2,720 pounds

**1.1.3.2 Volume of Cylinders**

Formula: V = $\pi \, x \, R^2$ x H

$\pi$ = 3.14     R = Radius   H = Height

Now lets try an example of volume calaculation for a cylinder. Refer to *Figure 22-6.*

Given:

R = 3 feet     H = 10 feet

V = $\pi \, x \, R^2$ x H

V = 3.14 x $3^2$ x 10

V = 3.14 x 3 x 3 x10

V = 282.6 $ft^3$

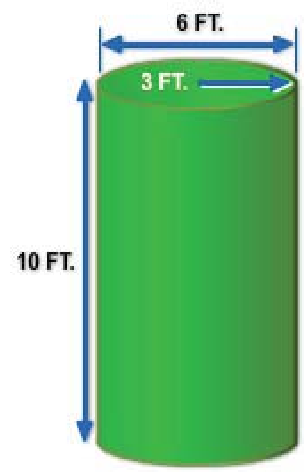



**Figure 22-6 — Volume of a cylinder.**

Now calculate a steel cylinder that is 1 inch thick and full of saltwater.

Given:

Volume of cylinder = 282.6 $ft^3$

Material Weight of saltwater = 64 lbs/ $ft^3$     Material Weight of steel = 40.8lbs/ $ft^3$

First, calculate the weight of a cylinder (CW) full of saltwater.

CW = V x MW     = 282.6 $ft^3$ x 64 lbs/ $ft^3$ = 18,086 lbs (18,087 rounded up)

But this is not the load weight, remember the weight of the container needs to be taken into account.

Now calculate the cylinder bottom plate weight (BWP).

BWP = $\pi \, x \, R^2$ x CW     3.14 x (3 x 3) x 40.8lbs/ $ft^3$ = 1154 lbs

Next calculate the cylinder wall weight (CWW).

CWW = $\pi$ x Circumference x H x MW 3.14 x 6 x 10 x40.8lbs/ ft$^3$ = 7687 lbs

Now total up all weight calculations to receive load weight

BWP + CWW + CW 1154 + 7687 + 18087 = 26928 lbs

## 1.2.0 Center of Gravity/Center of Balance

Jobsite accidents are often caused by lack of understanding that whenever a load is lifted, the center of gravity of the load will place itself vertically below the hook, regardless of the arrangement of the slings, lift beams, or other attachments. The reason is that the sum of the forces and moments needs to be zero for a body in equilibrium.

The center of gravity of a body is that point on the body through which the weight of the body could be considered to be concentrated for all orientations of the body. For a body whose weight per net volume is uniform, the center of gravity lies at its centroid. The center of gravity is the location where the center of the object's entire weight is theoretically concentrated and where the object will balance when it is lifted. Center of gravity is always a fixed point and does not change unless the object is altered. For a balanced lift, the object's center of gravity is always in line below the hook. If you have a high center of gravity and the attachment points are below the center of gravity, the load is more prone to tip over. If you have a low center of gravity and the attachment points are above the center of gravity, the load is NOT likely to tip over when lifted.

The manufacturers normally provide the center of gravity locations of equipment. However, manufacturers' drawings typically have more information than just the center of gravity location, and as the EO, you need to sift through all of the information and identify what is relevant. In some cases, unfortunately, there is not enough information. When this occurs, you must make conservative assumptions to proceed. You are responsible for contacting the appropriate rates and supervisors for lift validations.

Center of balance is point where an object is balanced, this point can be located anywhere on the object. Two points to remember, center of balance is always perpendicular to the center of gravity and directly below the center of gravity.

### 1.2.1 Process to Find the Center of Gravity

Follow the process below to determine an object's center of gravity:

1. Separate objects into known sections or components.
2. Determine section weights.
3. Measure distance from a reference end to center of balance for each section.
4. Mutiply weight by distance.
5. Add together and divide by total weight.

Use this process on all three dimensions.

Refer to *Figure 22-7* to see an example of finding the center of gravity.

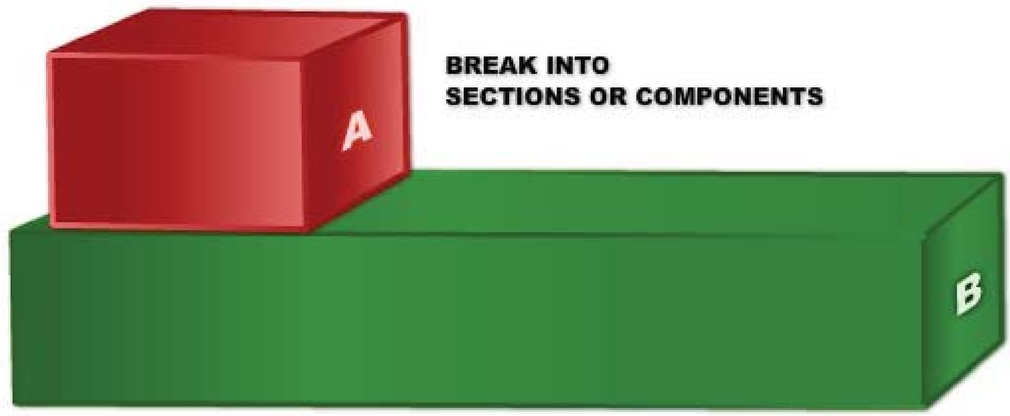



**Figure 22-7 — Finding the center of gravity.**

If you recall, you now must find the center of gravity for height and width. This is conducted in the same manner as described above, but along the height and width axis. Only then will you kow the true center of gravity.

## 1.3.0 Slings

One of the main components of any rigging arrangement is the sling or "choker." Slings come in any number of shapes, sizes, capacities, and types. The main types are wire rope, nylon, polyester round, chain, and wire mesh. These components will be discussed in more detail later in this chapter. Wire rope used in rigging is typically 6 x 19 or 6 x 37 class, and all types must meet ASME B30.9 criteria. All slings, regardless of type, must have a legible tag stating, among other things, its safe working load (SWL) when in a straight pull. The SWL does not account for how the sling is to be used, whether in a choke or basket hitch or on an angle. When placed in a choker configuration, the sling could be derated as much as 30 percent, while a true basket hitch (where both legs are vertical) will have twice the rated capacity.

### 1.3.1 Basket Hitches and D/d Ratio

One catch to the basket hitch that is often missed is what is called the D/d ratio. When a sling is bent around something with a large diameter, the outer pieces of the wire rope stretch very little. However, when the sling is bent around a small diameter, the outer pieces will stretch greatly, thus requiring a reduction in capacity. To determine this reduction, calculate the D/d ratio and then look it up in a table such as Figure 22-8. The D is the diameter of the item around which the sling is bent, and the d is the diameter of the sling. For example, a 1.5 inch sling has an SWL of 21 tons and will bend around something that is 6 inches in diameter weighing 37 tons. If the D/d ratio is ignored, the capacity appears to be twice the SWL of 21 tons for a basket SWL of 42 tons. However, the D/d must be factored. Thus, 6 inches/1.5 inches = 4 inches. Now, as *Figure 22-8* indicates, the efficiency is actually 75 percent of 42 tons or 31.5 tons. Thus, calculating the D/d ratio before the lift determines that the proposed sling would be overloaded by 17.5 percent, and a larger sling can be recommended.

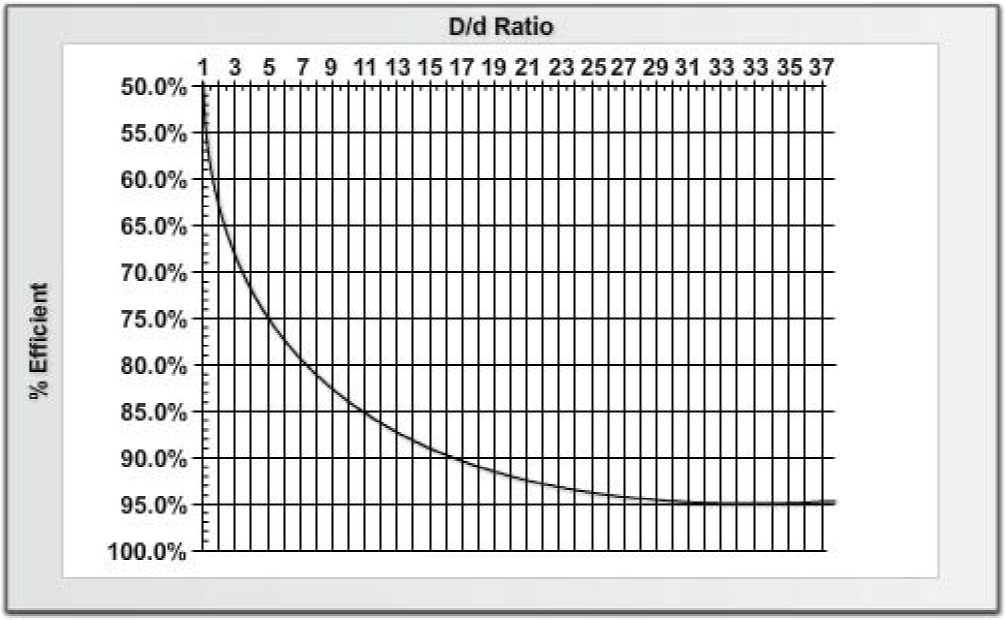



**Figure 22-8 — D/d ratio chart.**

### 1.3.2 Sling Angle

Sling angle is another area where a sling may need to be larger than thought. Note that the SWL is in straight pull. When the forces on a sling act on an angle, the forces that affect the sling will actually be greater. Refer to *Figure 22-9*.

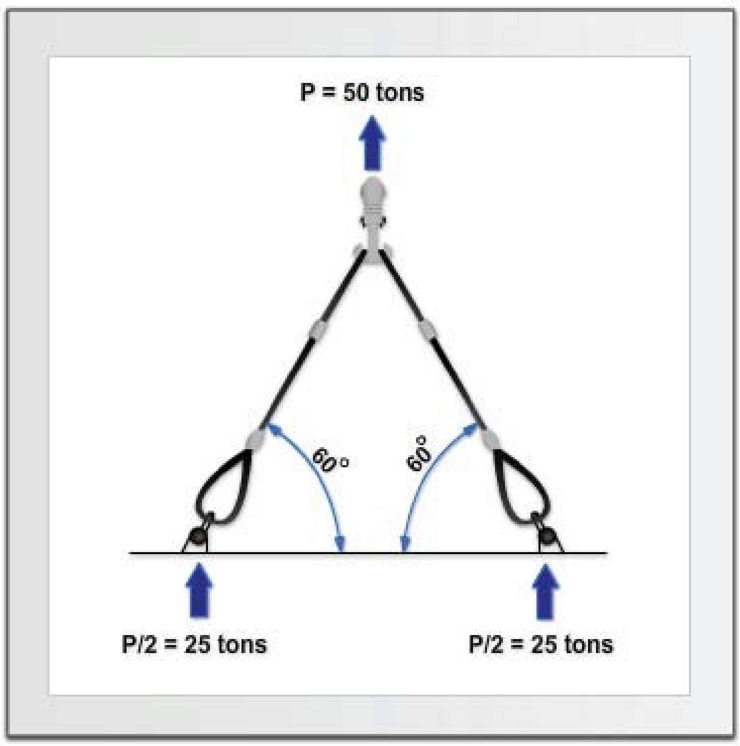



**Figure 22-9 — Sling angle.**

### 1.3.3 Bridles and Center of Gravity

Most jobsites use bridles of three or more legs on a regular basis. These items, while very useful and versatile, can be easily overloaded if not sized properly. The most common reason stems from the following logic: There are four pick points; therefore, each leg gets 25 percent of the load. However, assuming that the center of gravity is symmetrical to the lift points and that four or more pick points go to a single point, it is “statically indeterminate.” Statically indeterminate means that the true load in each sling cannot be mathematically determined. In reality, only two opposite slings actually take any load, while the other two slings just help balance. Other factors contribute to this as well such as one leg being longer/shorter than the other or lugs not at the same elevation. To solve this problem, size the bridle so that only two legs can handle the load or use a spreader.

# 2.0.0 NAVFAC P-307

One of the most important publications, you will reference as an EO is the Management of Weight Handling Equipment, NAVFAC P-307.

This publication provides requirements for the maintenance, inspection, test, certification, repair, alteration, operation, and/or use of weight handling equipment under the technical cognizance of the Naval Facilities Engineering Command (NAVFAC). Activities covered include Navy shore activities, the Naval Construction Force (NCF), Naval Special Operating Units (SOU), and the Naval Construction Training Center (NCTC). These are the minimum requirements for all applicable equipment. This publication meets or exceeds all applicable OSHA requirements for maintenance, inspection, testing, certification, repair, alteration, and operation of equipment covered herein.

## 2.1.0 Purpose

The purposes of this publication are:

a. To maintain the level of safety and reliability built into each unit of applicable equipment by the original equipment manufacturer (OEM).

b. To ensure optimum service life.

c. To provide training and qualification standards for all personnel involved with maintenance, inspection, test, certification, engineering, rigging and operation of WHE.

d. To ensure the safe lifting and controlling capability of WHE and promote safe operating practices through the engineering, inspection, test, certification, qualification, operation, and rigging requirements prescribed herein.

This publication is broken down into 14 sections. The section we will cover is Section 14 – Rigging Gear and Miscellaneous Equipment.

## 2.2.0 Section 14

Section 14 applies to the following equipment used in weight handling operations:

- Rigging gear (slings, shackles, eye bolts, swivel hoist rings, links, rings, turnbuckles, insulated links, etc.)
- Portable manual and powered hoists. These are manual and powered hoists that are mounted by means of an upper hook (the source of power—air, electric, or manual— is irrelevant).
- Portable load indicators (dynamometers, load cells, crane scales, etc.)
- Below the hook lifting devices as identified in ASME B30.20
- Portable A-frames, portable floor cranes, and portable gantries used for general lifting
- Cranes and hoists procured with, integral to, and used solely in support of larger machine systems (milling machines, press brakes, shore power booms, etc.).

### 2.2.1 Test and Inspection Program

Each activity shall establish a program for applicable equipment, including a documented initial inspection and load test followed by pre-use and documented periodic inspections (and periodic tests as noted).

Remove unsatisfactory equipment and gear from service and disposed of or repair it.

Segregate equipment and gear that is not yet in a test and inspection program or is currently out of service from gear that is in service.

The goals of a effective test and inspection program are as follows:

- Prevent personnel injury
- Identify sub-standard equipment
- Remove unsafe equipment
- Prevent damage to items handled

### 2.2.1.1 Load Test

Except as noted, give each piece of applicable equipment an initial load test. A certificate of load (proof) test from the supplier of purchased equipment will satisfy this requirement, provided the proof loads used meet or exceed the loads specified in NAVFAC P-307 Table 14-1. Frequencies for periodic load testing of applicable equipment are also shown in Table 14-1. For equipment where the OEM does not permit testing at the percentages shown, reduce the rated load such that the OEM's allowed test load will serve as the load test value.

For each test, the equipment shall withstand the load test for a minimum of two minutes (10 minutes for hoist, cranes, and crane structures) with no permanent deformation. For hoists, trolleys, and other moving machinery, lift (travel) through at least one revolution of all moving parts.

When testing wire rope and synthetic rope slings, ensure the slings are prevented from unlaying. (See discussion in following section). Where it is not practical to test locally fabricated special rigging gear (e.g., non-standard eye bolts made specifically for a particular application), the activity engineering organization shall approve the use of such gear.

### 2.2.1.2 Pre Use Inspection (Frequent Inspection)

The user shall visually inspect applicable equipment prior to each use to verify rated load, marking, inspection status, serial number, and condition. No documentation of pre-use inspection is required.

### 2.2.1.3 Periodic Inspection

NAVFAC P-307, Table 14-1 specifies periodic documented inspections for covered equipment. Rigging gear used exclusively for lifts of 100 pounds or less and gear with a safety factor of 10 with respect to the yield point of the material are excluded from these periodic inspection requirements.

### 2.2.2 Equipment Markings

Markings on each piece of equipment are the most apparent way for you, the user, to know P-307 requirements have been met.

Each piece of equipment must be clearly marked, whether tagged or engraved, with:

- Rated load of the equipment
- Date the next test or inspection cycle is due

- A unique serial number that will allow it to be retraced to its test and inspection record
- Manufacturer’s name or logo

Markings indicate that equipment is acceptable for use. Markings must be done in a manner that will not affect strength of component. Vibra-etch methods and low stress dot faced stamps are generally acceptable ways of marking equipment.

Contact Original Equipment Manufacturer (OEM) as necessary if you have any questions concerning where and how to mark. Refer to *Figure 22-10* for examples of equipment markings.


**Figure 22-10 — Equipment markings.**

Sometimes markings become hard to read due to wear, or they may even be removed during a repair process. Re-apply all markings that are hard to read or have been removed. Remember, all rigging equipment must be marked for you to use it in a weight handling operation.

# 3.0.0 WIRE ROPE

## 3.1.0 Fabrication

Wire rope is a highly specialized precision product adaptable to many uses and conditions of operation. To meet the exacting requirements of different types of service, it is designed and manufactured in a number of constructions and grades.

Wire rope is like a complex machine, composed of a number of precise, moving parts designed and manufactured to bear a very definite relationship to one another. In fact, many wire ropes contain more moving parts than most mechanisms that fall within the broad general term “machine.” For example a six-strand rope, consisting of approximately 46 wires per strand, contains a total of 276 individual wires, all of which must be able to move with respect to one another if the rope is to have the necessary flexibility during operation.

Wire rope may be manufactured by one of two methods. If the strands, or wires, are shaped to conform to the curvature of the finished rope before laying up, the rope is termed ***preformed wire rope***. If they are not shaped before fabrication, the wire rope is termed ***non-preformed wire rope***.

The most common type of manufactured wire rope is preformed. When cut, the wire rope tends not to unlay and is more flexible than non-preformed wire rope. Twisting non-preformed wire produces a stress in the wire which causes the strands to unlay when the wire is cut or broken.

## 3.2.0 Parts of Wire Rope

Wire rope is composed of three parts: ***wires***, ***strands***, and ***core*** (*Figure 22-11*). A predetermined number of wires of the same or different size are fabricated in a uniform arrangement of definite lay to form a strand. The required number of strands are then laid together symmetrically around the core to form the wire rope.

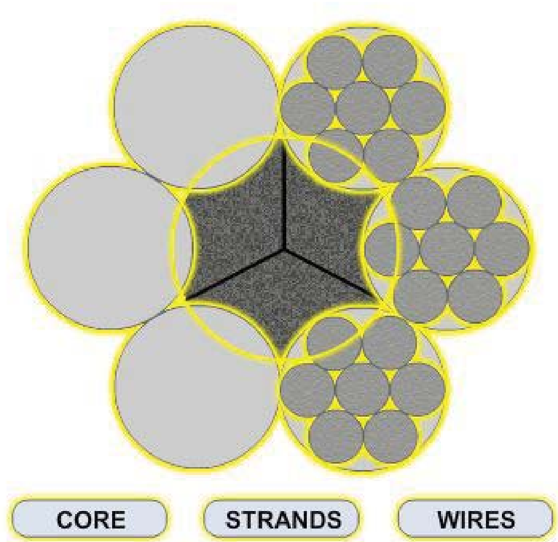


**Figure 22-11 – Parts of a wire rope.**

### 3.2.1 Wire

Wire rope varies in size and can consist of steel, iron, or other metals. The number of wires to a strand varies, depending on the intended purpose of the rope. Wire rope is designated by the number of strands per rope and the number of wires per strand. Thus a one-half inch, 6 x 19 rope has six strands with 19 wires per strand. It has the same outside diameter as a one-half inch, 6 x 37 rope that has six strands with 37 wires (of smaller size) per strand.

### 3.2.2 Strand

The design arrangement of a strand is called the construction. The wires in the strand may be all the same size or a combination of different sizes. *Figure 22-12* show some of the more typical wire rope constructions. The most common strand constructions you may encounter are as follows:

- Ordinary construction: Wires are all the same size.
- Seale construction: Each strand consists of three rings of wire. The first ring of wires around the center wire of the strand is of smaller diameter than the center and outer layers. Large diameter wires resist abrasion while smaller diameter wires provide flexibility.

- Warrington construction: Each strand has two layers of wire about a center wire. The outer layer consists of wires that are alternately large and small. This alternating wire size combines flexibility with abrasion resistance.
- Filler construction: Filler wire has small wires filling the voids between the rings of wire in the strand. These small wires are not counted when designating the number of wires in the strand. This construction type provides abrasion and fatigue resistance.
- Flattened construction: Strands are somewhat triangular in shape, and sometimes formed around a triangular center wire.

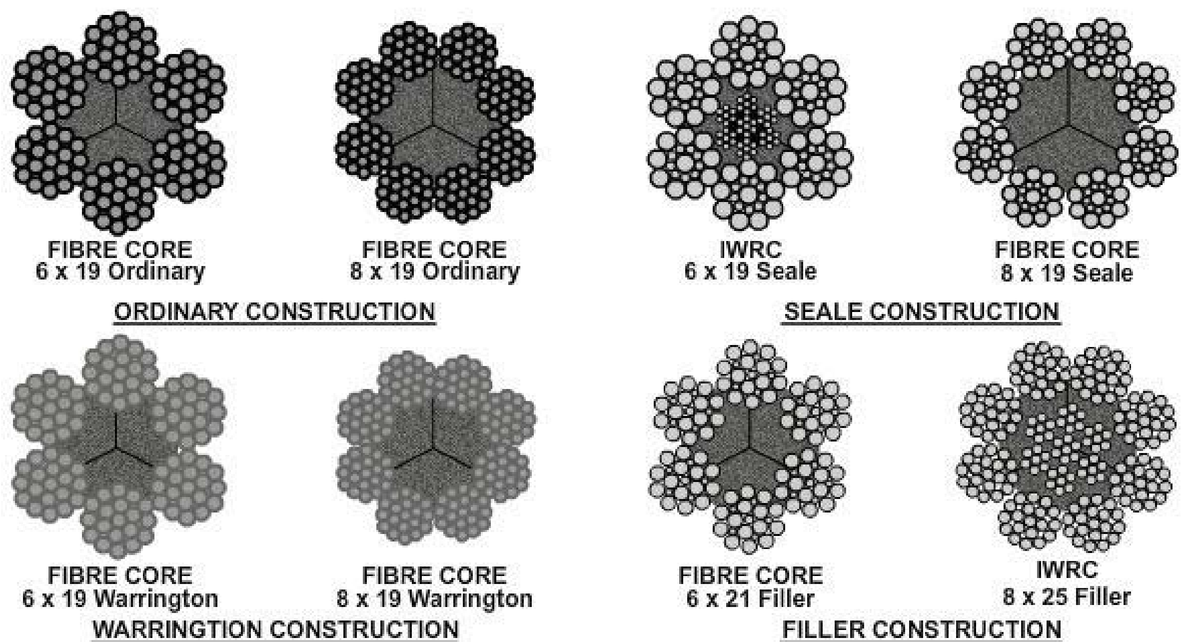



**Figure 22-12 — Common strand construction.**

### 3.2.3 Core

The wire rope core supports the strands laid around it. There are three types of wire rope core:

- **Fiber core** consists of a hard fiber, such as manila, hemp, plastic, paper, or sisal. The fiber core offers the advantage of increased flexibility. It also serves as a cushion to reduce the effects of sudden strain and acts as an oil reservoir to lubricate the wire and strands (to reduce friction). Wire rope with a fiber core is used when flexibility of the rope is especially important.
- **Wire strand core** resists more heat than a fiber core and also adds about 15 percent to the strength of the rope. However, the wire strand core makes the wire less flexible than a rope with a fiber core.

- **Independent wire rope core** (IWRC) is a separate wire rope over which the main strands of the rope are laid. This core strengthens the rope, provides support against crushing, and supplies maximum resistance to heat. Refer to *Figure 22-13.*

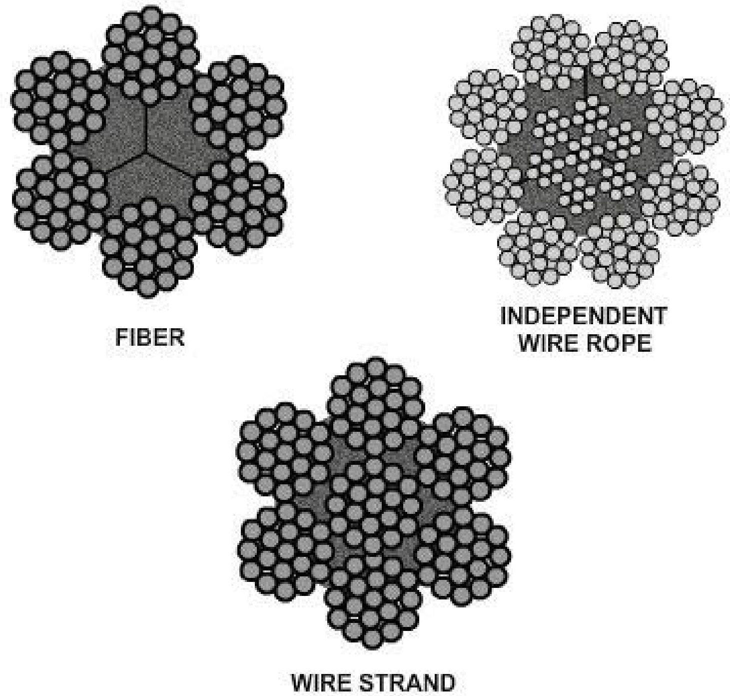



**Figure 22-13 — Core construction.**

## 3.3.0 Grades of Wire Rope

There are four primary grades of wire rope:

- Mild plow steel
- Plow steel
- Improved plow steel
- Extra improved plow steel

### 3.3.1 Mild Plow Steel Wire Rope

Mild plow steel wire rope is tough and pliable. It can stand repeated strain and stress and has a tensile strength (resistance to lengthwise stress) of from 200,000 to 220,000 pounds per square inch (psi). These characteristics make it desirable for cable tool drilling and other uses in which abrasion occurs.

### 3.3.2 Plow Steel Wire Rope

Plow steel wire rope is unusually tough and strong. This steel, which got its name from the original high-carbon crucible furnace steel used to produce plowshares, has a tensile strength of 220,000 to 240,000 psi. Plow steel wire rope is suitable for hauling, hoisting, and logging.

### 3.3.3 Improved Plow Steel Wire Rope

Improved plow steel (IPS) wire rope is one of the best grades of rope available and is the wire rope most commonly used in the NCF. This type of rope is stronger, tougher, and more resistant to wear than either mild plow steel or plow steel. Each square inch of IPS can stand a strain of 240,000 to 260,000 pounds. This makes it especially useful for heavy-duty service, such as on cranes with excavating and weight-handling attachments.

### 3.3.4 Extra Improved Plow Steel Wire Rope

Extra Improved Plow Steel (EIP) is 15% stronger than IPS. Various manufacturers have their own name for this grade. It was developed for applications, such as rotary oil-well drilling, needing greater safety factors without a diameter increase and for maximum resistance to abrasive wear, such as that resulting from draglines in strip mining through rocky terrain. This premium grade has tensile strength ranging from 280,000 to 340,000 psi.

## 3.4.0 Lay of Wire Rope

Lay refers to the direction of the twist of the wires in a strand and to the direction that the strands are laid in the rope. In some instances, both the wires in the strand and the strands in the rope are laid in the same direction; in other instances, the wires are laid in one direction and the strands are laid in the opposite direction. The lay of a particular rope depends on its intended use. Most manufacturers specify the types and lays of wire rope to be used on their piece of equipment. Always consult the operator’s manual for proper application.

There are five types of lays used in wire rope (*Figure 22-14*).

### 3.4.1 Right Regular Lay

The wires in the strands are laid to the left, while the strands are laid to the right to form the wire rope.

### 3.4.2 Left Regular Lay

The wires in the strands are laid to the right, while the strands are laid to the left to form the wire rope. In this lay, each step of fabrication is exactly opposite from the right regular lay.

### 3.4.3 Right Lang Lay

The wires in the strands and the strands in the rope are laid in the same direction; in this instance the lay is to the right.

### 3.4.4 Left Lang Lay

The wires in the strands and the strands in the rope are are also laid in the same direction; in this instance the lay is to the left.

### 3.4.5 Reverse Lay

The wires in one strand are laid to the right, the wires in the nearby strand are laid to the left, the wires in the next strand are to the right, and so forth, with alternate directions from one strand to the other. Then all the strands are laid to the right.

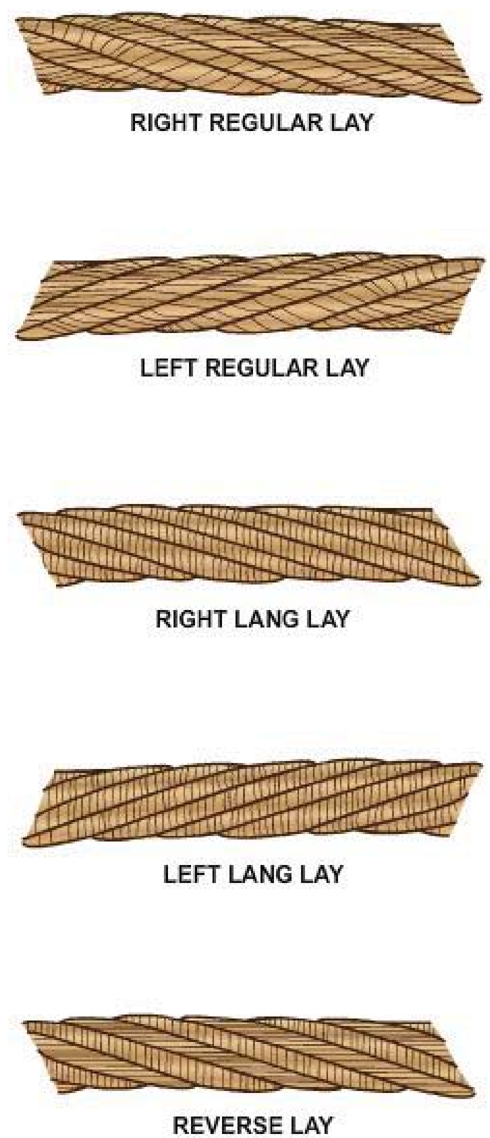



**Figure 22-14 — Lay of wire rope.**

## 3.5.0 Lay Length of Wire Rope

The length of a rope lay is the distance measured parallel to the center line of a wire rope in which a strand makes one complete spiral (or turn) around the rope. The length of a strand lay is the distance measured parallel to the center line of the strand in which one wire makes one complete spiral turn around the strand. Lay length measurement is shown in *Figure 22-15*.

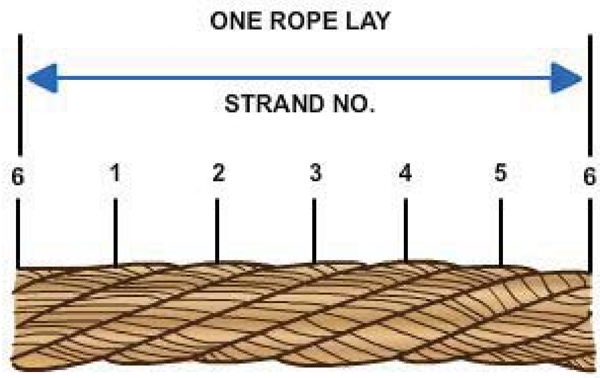


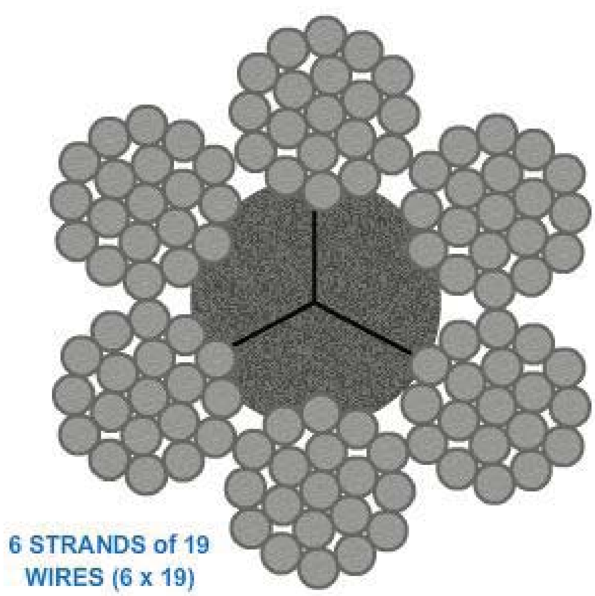

**Figure 22-15 – Lay length of wire rope.**

## 3.6.0 Characteristics of Wire Rope

The NCF use several types of wire, typically those with 6, 7, 12, 19, 24, or 37 wires in each strand. Usually the wire rope has six strands laid around the core.

The two most common types of wire rope are 6 x 19 and 6 x 37 (*Figures 22-16, and 22-17*). The 6 x 19 type, which has 6 strands with 19 wires in each strand, is the stiffest and strongest construction of the wire rope and the most suitable for general hoisting operations. The 6 x 37 wire rope, six strands with 37 wires in each strand, is very flexible, making it most suitable for cranes and other pieces of equipment in which sheaves are smaller than usual. The wires in the 6 x 37 are smaller than the wires in the 6 x 19 and, consequently, do not stand as much abrasive wear.

Consider several factors when selecting a wire rope for use in a particular kind of operation. There is not a wire rope in existence that equally withstands all kind of wear and stress. Because of this, selecting a rope is often a matter of compromise, sacrificing one quality to have another more critical characteristic.




**Figures 22-16 – 6 x 19 wire ropes.**

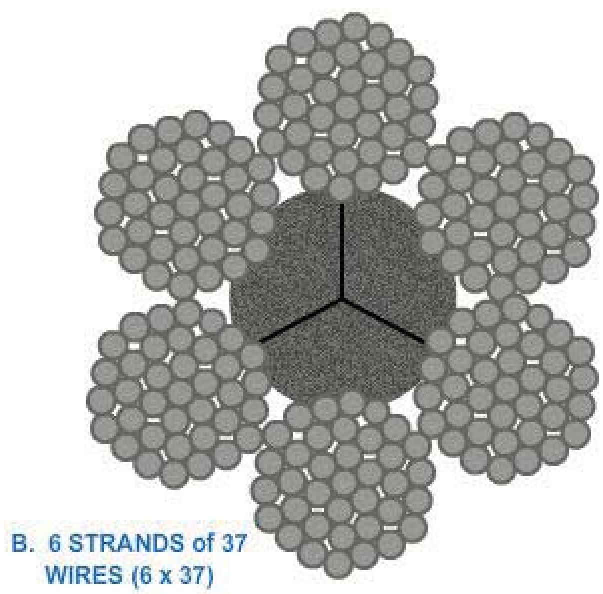



**Figure 22-17 – 6 x 37 wire rope.**

### 3.6.1 Tensile Strength

***Tensile strength*** is the strength necessary to withstand a certain maximum load applied to the rope. It includes a reserve of strength measured in a so-called factor of safety.

### 3.6.2 Crushing Strength

Crushing strength is the strength necessary to resist the compressive and squeezing forces that distort the cross section of a wire rope as it runs over sheaves, rollers, and hoist drums when under a heavy load. Regular lay rope distorts less in these situations than lang lay.

### 3.6.3 Fatigue Resistance

Fatigue resistance is the ability to withstand the constant bending and flexing of wire rope that runs continuously on sheaves and hoist drums. Fatigue resistance is important when the wire rope must run at high speeds. Such constant and rapid bending of the rope can break individual wires in the strands. Lang lay ropes are best for service requiring high fatigue resistance. Ropes with smaller wires around the outside of their strands also have greater fatigue resistance, since these strands are more flexible.

### 3.6.4 Abrasion Resistance

***Abrasion*** resistance is the ability to withstand the gradual wearing away of the outer metal as the rope runs across sheaves and hoist drums. The rate of abrasion depends mainly on the load carried by the rope and its running speed. Generally, abrasion resistance in a rope depends on the type of metal of which the rope is made and the size of the individual outer wires. Wire rope made of the harder steels, such as improved plow steel, have considerable resistance to abrasion. Ropes that have larger wires forming the outside of their strands are more resistant to wear than ropes having smaller wires which wear away more quickly.

### 3.6.5 Corrosion Resistance

***Corrosion*** resistance is the ability to withstand the dissolution of the wire metal that results from chemical attack by moisture in the atmosphere or elsewhere in the working environment. Ropes, such as guy wires, that are put to static work may be protected from corrosive elements by paint or other special dressings. Wire rope may also be galvanized for corrosion protection. Most wire ropes used in crane operations must rely on their lubricating dressing to double as a corrosion preventative.

## 3.7.0 Measuring Wire Rope

Wire rope is designated by its diameter in inches, as shown in *Figure 22-18*. The correct method of measuring the wire rope is to measure from the top of one strand to the top of the strand directly opposite it. Measuring across two side by side strands is not correct.

To ensure an accurate measurement of the wire rope's diameter, always measure the rope at three places, at least five feet apart. Use the average of the three measurements as the diameter of the rope.

**NOTE**

A crescent wrench provides an expedient means to measure wire rope.

## 3.8.0 Wire Rope Safe Working Load

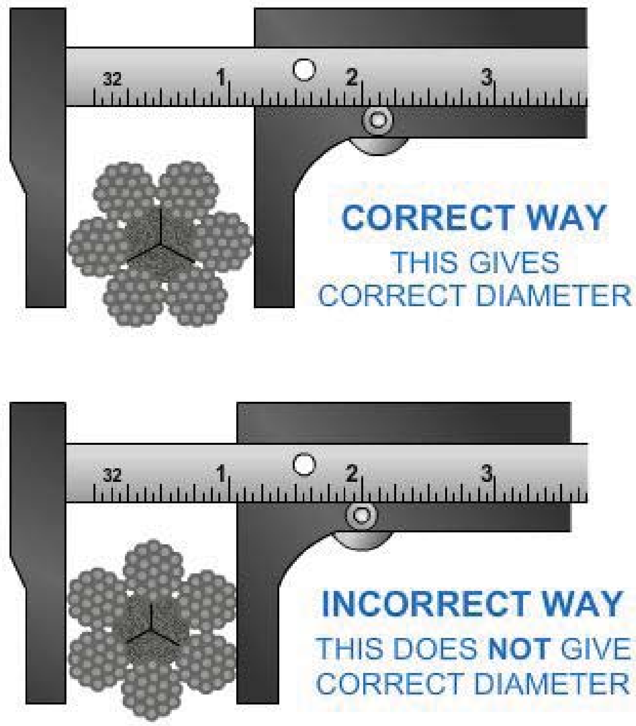



**Figure 22-18 — Correct and incorrect methods of measuring wire rope.**

The safe working load (SWL) of wire rope is the load that can be applied and still obtain the most efficient service and prolong the life of the rope.

The formula for computing the SWL of a wire rope is the diameter of the rope squared, multiplied by 8 (D x D x 8 = SWL in tons).

Example: The wire rope is 1/2 inch in diameter. Compute the SWL for the rope.

The first step is to convert the 1/2 into a decimal number by dividing the bottom number of the fraction into the top number of the fraction: (1 divided by 2 = .5).
Next, compute the SWL formula: (.5 x .5 x 8 = 2 tons). The SWL of the 1/2 inch wire rope is 2 tons.

**NOTE**

Do NOT downgrade the SWL of wire rope if it is old, worn, or in poor condition. Cut up and discard wire rope in these conditions.

## 3.9.0 Wire Rope Failure

Common causes of wire rope failure include:

- Using an incorrect size, construction, or grade of rope
- Dragging rope over obstacles
- Lubricating improperly
- Operating over sheaves and drums of inadequate size
- Overriding or cross winding on drums
- Operating over sheaves and drums with improperly fitted grooves or broken flanges
- The rope jumping off sheaves
- Exposing ropes to acid and/or other corrosive liquids/gases
- Using an improperly attached fitting
- Allowing grit to penetrate between the strands, promoting internal wear
- Subjecting the rope to severe or repetitive overload
- Using an excessive ***fleet angle***

## 3.10.0 Handling and Care of Wire Rope

To maximize the safe, dependable service of wire rope, take care to perform the maintenance necessary to keep the wire rope in good condition. Various ways of caring for and handling wire rope are discussed below.

### 3.10.1 Coiling and Uncoiling

Once a new reel is open, it may be coiled or faked down (laid in a coil or series of long loops to allow the rope to run freely without kinking) like line. For left lay wire rope, coil counterclockwise. For right lay wire rope, coil clockwise. Because of the resilience of the wire, it can be resistant to being coiled down. When this occurs, it is not useful to force the wire down the turn because it will just spring up again. Instead, throw the wire in a back turn (*Figure 22-19)*, and it will lie down properly. A wire rope, when faked down, runs right off. But when wire rope is wound in a coil, it has to be unwound manually.

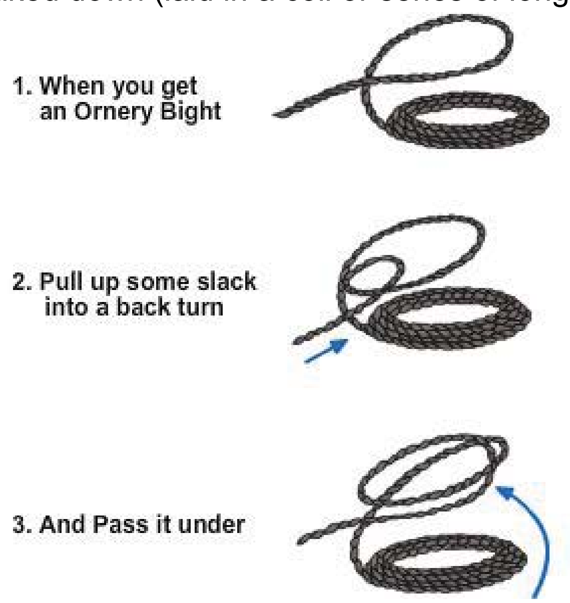



**Figure 22-19 – Throwing a back turn.**

Wire rope tends to kink during uncoiling or unreeling, especially if it has been in use for a long time. A kink can cause a weak spot in the rope that wears out more quickly than the rest of the rope.

A good method for unreeling wire rope is to run a pipe or rod through the center and mount the reel on drum jacks or other supports so the reel is off the ground. In this position, the reel turns as the rope unwinds, and the rotation of the reel helps keep the rope strait. During unreeling, pull the rope strait forward and try not to rush. To avoid kinking, NEVER unreel wire rope from a stationary reel. Refer to *Figure 22-20*.

To uncoil a small twist of wire rope, simply stand the coil on edge and roll it along the ground like a wheel or hoop. Do not lay the coil flat on the floor/ground and uncoil it by pulling on the end- such practice can kink and/or twist the rope.

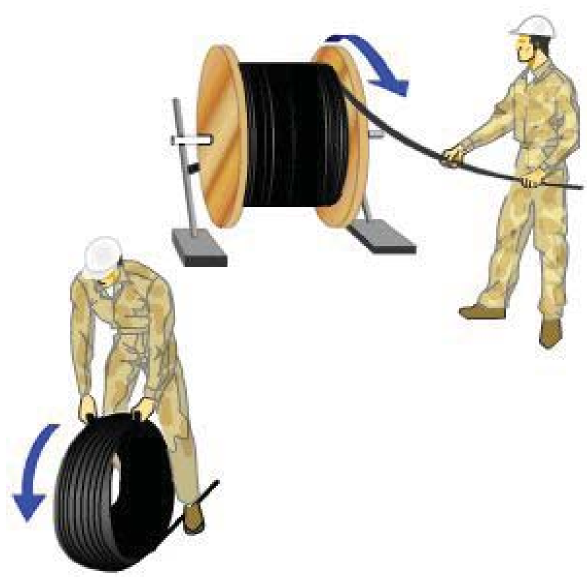


**Figure 22-20 — Unreeling wire rope and uncoiling wire rope.**

### 3.10.2 Kinks

One of the most common forms of damage resulting from improper handling of wire rope is kink development. A kink starts with the formation of a loop. A loop that is not pulled tight enough to set the wires or strands of the rope into a kink can be removed by turning the rope at either end in the direction appropriate to restore the lay (Figure 22-21).

If you attempt to remove a loop simply by pulling it tight, a kink will result, and the rope will be irreparably damaged. Kinking is preventable through proper uncoiling and unreeling methods and by handling the rope correctly at all times.

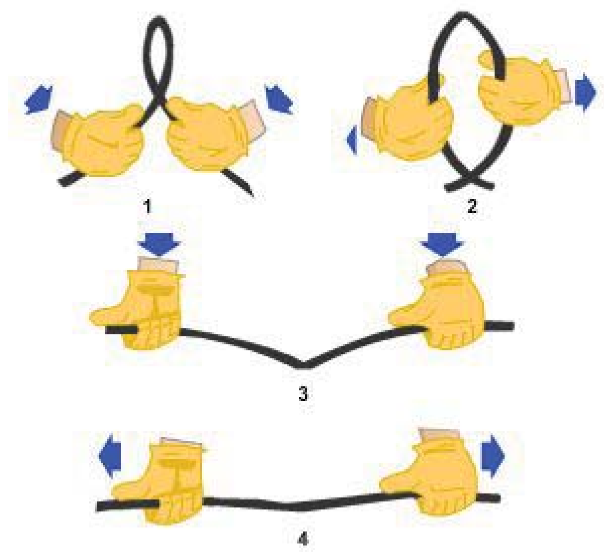



Figure 22-21 – Removing a loop.

### 3.10.3 Drum Winding

Spooling wire rope on a crane hoist drum causes a slight rotating tendency due to the spiral lay of the strands. Two types of hoist drums are used for spooling wire rope:

- Grooved drum: On grooved drums, the grooves generally give sufficient control to wind the wire rope properly, whether it is right or left lay rope.
- Smooth-Faced Drum: On smooth-faced drums, the only influence on the wire rope in winding the first layer is the fleet angle. The slight rotational tendency of the rope can be used as an advantage in keeping the winding tight and uniform.

**NOTE**

Using the wrong type of wire rope lay causes the rotational tendency of the rope to be a disadvantage because it results in loose and non-uniform rope winding on the hoist drum.

*Figure 22-22* shows drum winding diagrams for selection of the proper lay of rope. Standing behind the hoist drum and looking toward an oncoming overwind rope, the rotating tendency of right lay rope is toward the left; whereas, the rotating tendency of a left lay rope is toward the right.

Refer to *Figure 22-22*. With overwind reeving and a right lay rope on a smooth-faced drum, the wire rope bitter end attachment to the drum flange should be at the left flange. With underwind reeving and a right lay rope, the wire rope bitter end attachment should be at the right flange.

When wire rope is run off one reel onto another or onto a winch or drum, it should be run from TOP TO TOP or from BOTTOM TO BOTTOM, as shown in *Figure 22-23*.

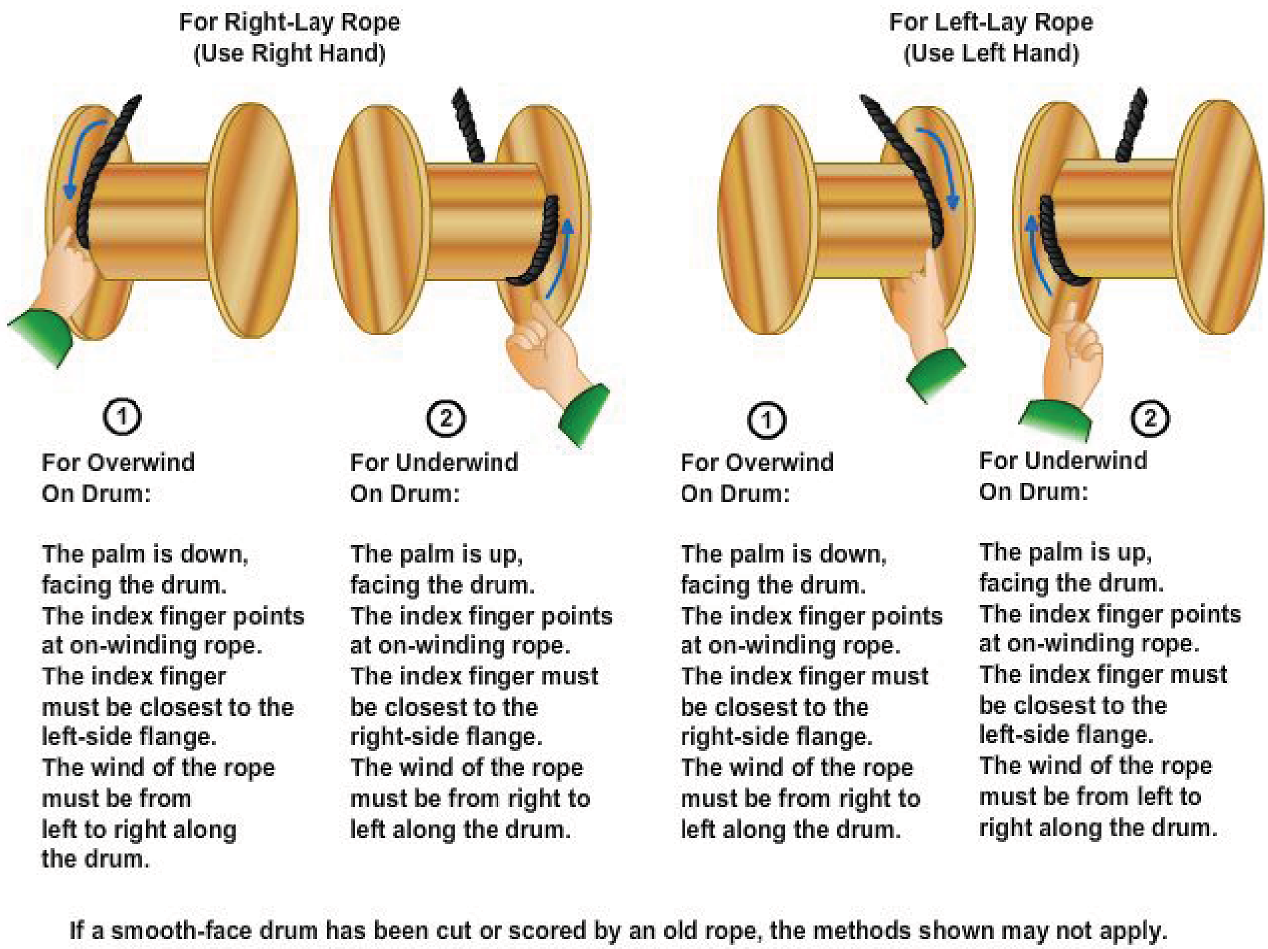



**Figure 22-22 — Different lays of wire rope winding on hoist drums.**

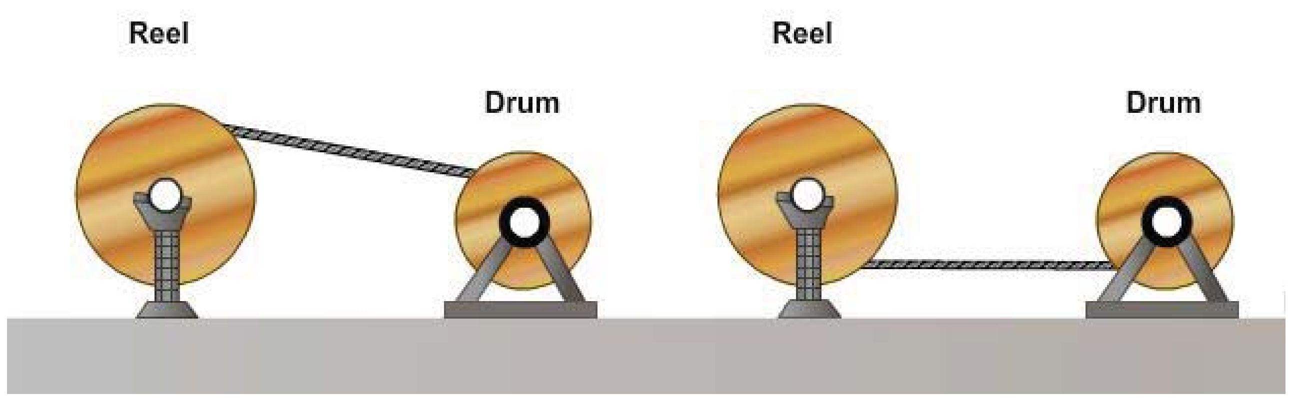



**Figure 22-23 — Transferring wire rope from reel to drum.**

### 3.10.4 Fleet Angle

The fleet angle is formed by running wire rope between a sheave and a hoist drum whose axles are parallel to each other, as shown in *Figure 22-24*. Too large a fleet angle can cause the wire rope to climb the flange of the sheave and can also cause the wire rope to climb over itself on the hoist drum.

### 3.10.5 Sizes of Sheaves

The diameter of a sheave should never be less than 20 times the diameter of the wire rope. An exception is 6 x 37 wire for which a smaller sheave can be used, because this wire rope is more flexible.

Use the chart shown in *Table 22-2* to determine the minimum sheave diameter for wire rope of various diameters and construction.

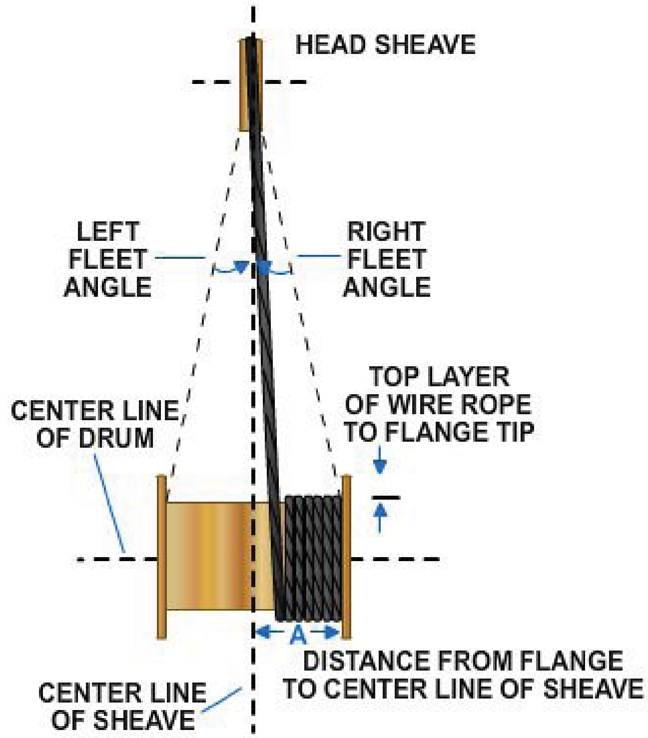



**Figure 22-24 Fleet angle relationship.**

**Table 22-2 — Suggested minimum tread diameter of sheaves and drums.**

| **Rope diameter in inches** | **Minimum tread diameter in inches for given rope construction *** | | | |
|---|---|---|---|---|
| | 6 x 7 | 6 x 19 | 6 x 37 | 8 x19 |
| 1/4 | 10 1/2 | 8 1/2 | | 6 1/2 |
| 3/8 | 15 3/4 | 12 3/4 | 6 3/4 | 9 3/4 |
| 1/2 | 21 | 17 | 9 | 13 |
| 5/8 | 26 1/4 | 21 1/4 | 11 1/4 | 16 1/4 |
| 3/4 | 31 1/2 | 25 1/2 | 13 1/2 | 19 1/2 |
| 7/8 | 36 3/4 | 29 3/4 | 15 3/4 | 22 3/4 |
| 1 | 42 | 34 | 18 | 26 |
| 1 1/8 | 47 1/2 | 38 1/4 | 20 1/2 | 29 1/4 |
| 1 1/4 | 52 1/2 | 42 1/2 | 22 1/2 | 32 1/2 |
| 1 1/2 | 63 | 51 | 27 | 39 |
| *** Rope construction is in strands times wires per strand**. | | | | |

### 3.10.6 Reverse Bends

Whenever possible, place drums, sheaves, and blocks used with wire rope to avoid reverse or S-shaped bends. Reverse bends cause the individual wires or strands to shift too much and increase wear and fatigue. For a reverse bend, the drums and blocks affecting the reversal should be of a larger diameter than ordinarily used and should be spaced as far apart as possible.

### 3.10.7 Seizing and Cutting

Wire rope makers are careful to lay each wire in the strand and each strand in the rope under uniform tension. If the ends of the rope are not secured properly, the original balance of tension is disturbed and maximum service is not possible because the load weight ends up being unevenly distributed. Before cutting steel wire rope, place seizing on each side of the cutting point (*Figure 22-25*).

Determining the size and number of seizings and the distance between them depends on several rules of thumb:

- The number of seizings applied is equal to approximately three times the rope's diameter.
- The width of each seizing is between one and one and a half times as long as the diameter of the rope.
- Space seizing a distance equal to twice the wire rope's diameter.

A common method used to make a temporary wire rope seizing involves winding the seizing wire uniformly, using tension on the wire. After taking the required number of turns, twist the ends of the wires counterclockwise by hand so that the twisted portion of the wires are near the middle of the seizing. Grasp the ends with end-cutting nippers. Cut the ends and pound them down on the rope, then use a serving bar (or iron) to increase tension on the seizing wire when putting on the turns.

A wire rope can be cut in a number of ways. One effective and simple method is to use a hydraulic wire rope cutter.

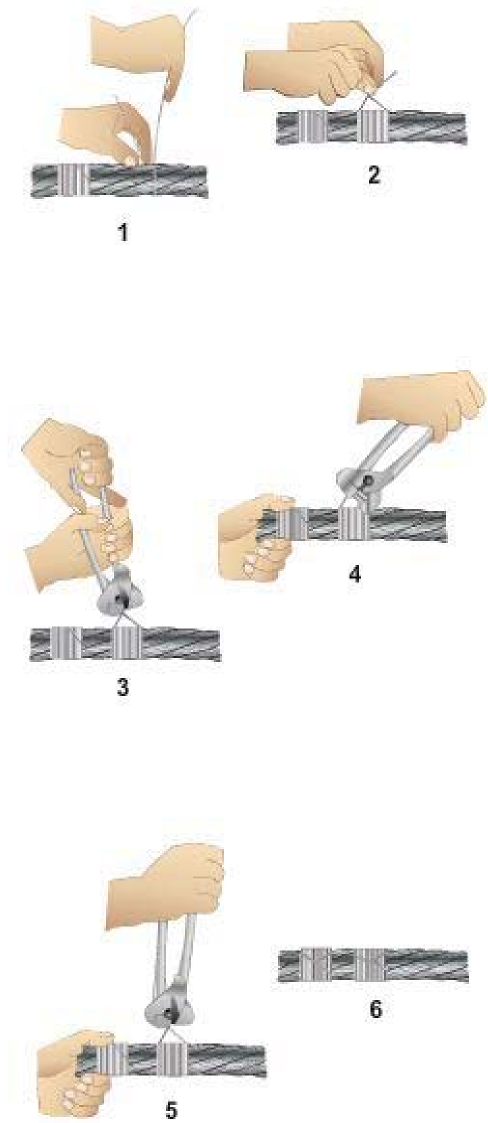



**Figure 22-25 — Seizing wire rope.**

Seize all wire before cutting it, then place the rope in the cutter so that the blade comes between the two central seizings. With the release valve closed, jack the blade against the rope at the location of the cut and continue to operate the cutter until the cut is complete.

## 3.11.0 Wire Rope Maintenance

Wire rope bending around hoist drums and sheaves will wear like any other metal article, so lubrication is just as important to an operating wire rope as it is to any other piece of working machinery. For a wire rope to operate correctly, its wires and strands must be free to move. Friction from corrosion or lack of lubrication shortens the service life of wire rope.

Deterioration from corrosion is more dangerous than that from wear, because corrosion ruins the inside wires, a process hard to detect by inspection. Deterioration caused by wear can be detected by conducting internal and external inspections.

### 3.11.1 Inspections

Unless experience with specific operating conditions indicates that more frequent inspections are required, visually inspect all running wire rope in service quarterly to determine whether deterioration has resulted in appreciable loss of original strength and constitutes a safety hazard.

#### 3.11.1.1 External Inspection

The external inspection criteria for general usage running wire rope is as follows:

A. Reduction of nominal rope diameter due to loss of core support or internal or external corrosion or wear of individual outside wires. The diameter shall be measured in a circumscribing circle in six or more places on the wire rope, as shown in *Figure 22-18*.
B. Number of broken outside wires and degree of distribution or concentration of broken wires.
C. Corroded, pitted, or broken wires at the end connections.
D. Corroded, cracked, bent, worn, or improperly applied end connections.
E. Severe kinking, crushing, or distortion of rope structure.
F. Evidence of heat damage from any cause.

#### 3.11.1.2 Internal Inspection

A wire rope can be opened for internal inspection only when completely relaxed. Using care to avoid damaging the strands or core, open the wire rope in six or more places, by working a marlin spike beneath two strands. Carefully rotate the spike to expose the core and underside of the strands. Inspect for evidence of internal corrosion, broken wires, or core failure. Give particular attention to the wire rope in areas close to end fittings, those lengths that pass over sheaves, onto drums, or that remain exposed to or immersed in seawater. If a wire rope has been opened properly and carefully, and internal condition does not show cause for removal, the strands can be returned to their original working positions without distorting the wire rope or impairing future usefulness. Only qualified personnel shall be authorized to inspect wire rope.

#### 3.11.1.3 Rejection Criteria

The following is a list of conditions that indicate a wire rope should be removed from service:

A. The nominal rope diameter is reduced by more than the amount shown in *Table 22-3* for the applicable size rope, or there is an unexpected increase in lay length as compared to previous lay length measurements

**Table 22-3 — Wire rope allowable diameter reduction.**

| Rope Diameter (Inches) | Maximum Allowable Nominal Diameter Reduction (Inches) |
|---|---|
| 5/16 and smaller | 1/64 |
| 3-8 to 1/2 | 1/32 |
| 9/16 to 3/4 | 3/64 |
| 7/8 to 1 1/8 | 1/16 |
| 1 1/4 to 1 1/2 | 3/32 |
| 1 9/16 to 2 | 1/8 |
| 2 1/8 to 2 1/2 | 5/32 |

B. Six broken wires in one rope lay length, or three broken wires in one strand lay length

C. One broken wire within one rope lay length of any end fitting

D. Wear of 1/3 the original diameter of outside individual wires, evidenced by flat spots almost the full width of the individual wire, extending one lay length or more

E. Pitting due to corrosion, or nicks, extending one lay length or more

F. Severe kinking, crushing, or any other damage resulting in distortion of the rope structure

G. Evidence of internal corrosion, broken wires on the underside of strands or in the core

### 3.11.2 Lubrication

Both internal and external lubrication protect a wire rope against wear and corrosion. Internal lubrication can be properly applied only when the wire rope is being manufactured, and manufacturers customarily coat every wire with a rust-inhibiting lubricant and lay it into the strand. The core is also lubricated in manufacturing.

Lubrication applied in the field is designed not only to maintain surface lubrication but also to prevent the loss of the internal lubrication provided by the manufacturer. The Navy issues an asphaltic petroleum oil that must be heated before using. This lubricant is known as Lubricating Oil for Chain, Wire Rope, and Exposed Gear and comes in two types:

- Type I, Regular: This type of lubricant does not prevent rust and is used where rust prevention is unnecessary. For example, elevator wires used inside structures that are not exposed to the weather, but still require lubrication.
- Type II, Protective: A lubricant and an anti-corrosive, it comes in three grades:
    - Grade A: For cold weather (60°F and below)
    - Grade B: For warm weather (between 60°F and 80°F)
    - Grade C: For hot weather (80°F and above)

Apply the oil, issued in 25-pound or 35-pound buckets and also in 100-pound drums, with a stiff brush, or draw the wire rope through a trough of hot lubricant (Refer to *Figure 22-26*). The frequency of application depends upon service conditions; as soon as the last coating has appreciably deteriorated, renew it.

**CAUTION**

Avoid prolonged skin contact with oils and lubricants. Consult the Materials Safety Data Sheet (MSDS) on each item before use for precautions and hazards.

A good lubricant to use when working in the field, as recommended by *Naval Ships Technical Manual Chapter 613*, is Mil-Spec lubricant (MIL-G-18458).

**Figure 22-26 — Trough method of lubricating wire rope.**

Do not lubricate wire rope that works a dragline or other attachments that normally bring the wire rope in contact with soils. The lubricant will pick up fine particles of material, and the resulting abrasive action will be detrimental to both the wire rope and sheave.

As a safety precaution, always wipe off any excess oil when lubricating wire rope, especially with hoisting equipment. Too much lubricant can get into brakes or clutches and cause them to fail. When machinery is in use, its motion may sling excess oil around and over crane cabs and onto catwalks, making them unsafe.

**NOTE**

Properly dispose of wiping rags and used or excess lubricant as hazardous waste. See your supervisor for details on local disposal requirements.

## 3.12.0 Wire Rope Attachments

Many attachments can be fitted to the ends of wire rope, so the rope can be connected to other wire ropes, pad eyes, or equipment.

### 3.12.1 Wedge Socket

The wedge socket is the most often used attachment for connecting ends of wire rope to pad eyes or like fittings on cranes and earthmoving equipment (*Figure 22-27*). The socket is always applied to the bitter end (the end of a rope that is tied off) of the wire rope.

**NOTE**

The wedge socket has only 70 percent of the breaking strength of the wire rope due to the crushing action of the wedge.

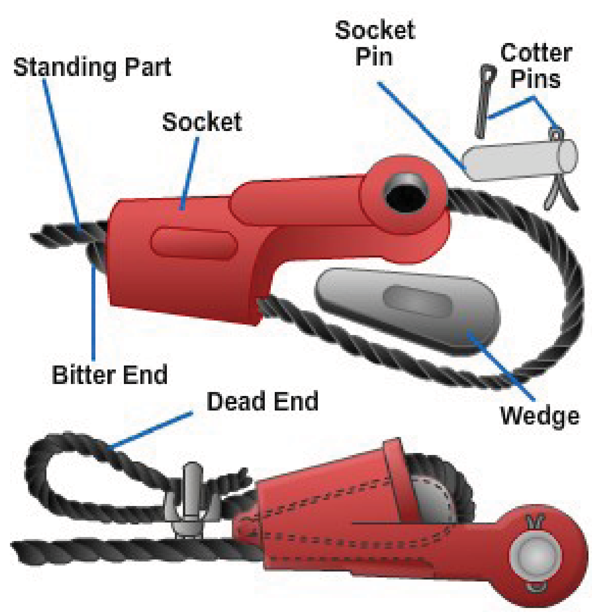



**Figure 22-27 – Wedge socket.**

### 3.12.2 Speltered Socket

Speltering is the best way to attach a closed or opened socket in the field. Speltering is the process of attaching the socket to the wire rope by pouring hot zinc or an exopy resin compound around it, as shown in *Figure 22-28*. Only qualified personnel should perform speltering.

Forged steel speltered sockets are as strong as the wire rope itself; they are required on all cranes used to lift personnel, ammunition, acids, and other dangerous materials.

**NOTE**

Spelter sockets develop 100 percent of the breaking strength of the wire rope.

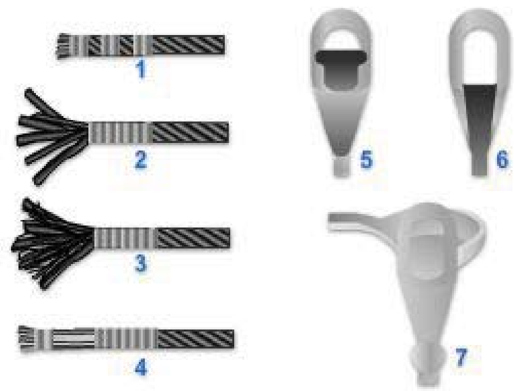



**Figure 22-28 — Speltering a socket.**

### 3.12.3 Wire Rope Clips

Wire rope clips make eyes in wire rope, as shown in *Figure 22-29*. The U-shaped part of the clip with the threaded ends is the U-bolt; the other part is the saddle. The saddle is stamped with the diameter of the wire rope that the clip will fit. Always place a clip with the U-bolt on the bitter end, not on the standing part of the wire rope. If clips are attached incorrectly, the standing part of the wire rope will be distorted or have mashed spots. A rule of thumb when attaching a wire rope clip is NEVER to saddle a dead horse.

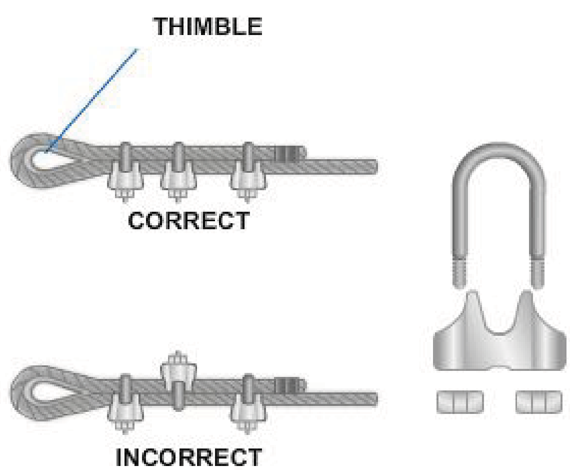



**Figure 22-29 — Wire rope clips.**

Two simple formulas for figuring the number of wire rope clips needed are as follows:

- 3 x the wire rope diameter + 1 = Number of clips
- 6 x the wire rope diameter = Spacing between clips.

Another type of wire rope clip is called the twin-base clip, often referred to as the universal or two clamp (*Figure 22-30*). Both parts of this clip are shaped to fit the wire rope so that the clip cannot be attached incorrectly. The twin-base clip allows for a clear 360-degree swing with the wrench when tightening the nuts.

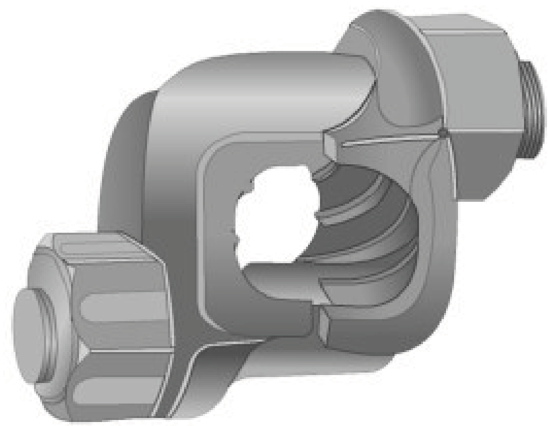


**Figure 22-30 – Twin-base wire rope clip.**

### 3.12.4 Thimble

When an eye is made in a wire rope, a metal fitting called a thimble is usually placed in the eye, as shown in *Figure 22-29*. The thimble protects the eye against wear. Wire rope eyes with thimbles and wire rope clips can hold approximately 80 percent of the wire rope strength.

After the eye made with clips has been strained, retighten the clip nuts. Check now and then for tightness or damage to the rope caused by the clips.

### 3.12.5 Swaged Connections

Swaging makes an efficient and permanent attachment for wire rope, as shown in *Figure 22-31*. A swaged connection is made by compressing a steel sleeve over the rope by using a hydraulic press. When the connection is made correctly, it provides 100 percent of the capacity of the wire rope.

Carefully inspecting the wires leading into these connections is important because of the pressure put upon the wires in this section. If there is one broken wire at the swaged connection, or there is a crack in the swage, replace the fitting.

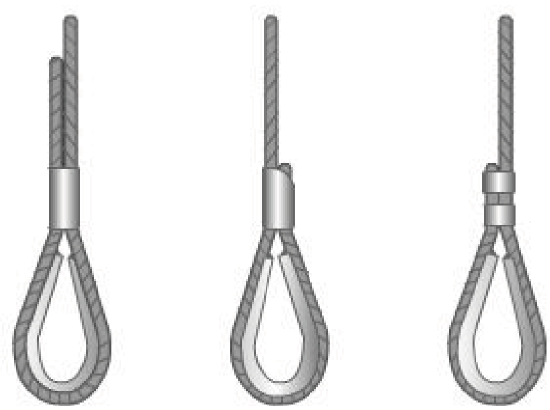


**Figure 22-31 — Swaged connections.**

### 3.12.6 Hooks and Shackles

Hooks and shackles are handy for hauling or lifting loads without tying them directly to the object with a line, wire rope, or chain. They can be attached to wire rope, fiber line, blocks, or chains. Shackles should be used for loads too heavy for hooks to handle.

When hooks fail due to overloading, they usually straighten out and lose or drop their load. When a hook is bent, DO NOT straighten it and put it back into service. Instead, cut it in half (with a cutting torch) and discard it.

Inspect hooks at the beginning of each work day and before lifting a full-rated load. If it is unclear whether the hook will bear the intended load, use a shackle. Use hooks that close and lock where there is danger of catching on an obstruction, particularly in hoisting buckets, cages, or skips, and especially during shaft work. Hooks and rings used with a chain should have about the same length as the chain.

Follow the manufacturers' recommendations in determining the SWL's of various sizes and types of specific and identifiable hooks. Test all hooks for which no applicable manufacturers' recommendations are available to twice the intended SWL before initially putting them into use.

Mousing is a technique often used to close the open section of a hook to keep slings, straps, and similar attachments from slipping off the hook, as shown in *Figure 22-32*.

Mouse hooks with rope yarn, seizing wire, or a shackle. When using rope yarn or wire, make 8 or 10 wraps around both sides of the hook. To finish off, make several turns with the yarn or wire around the sides of the mousing, and then tie the ends securely.

Two types of shackles used in rigging are the anchor (*Figure 22-33*) and the Chain (*Figure 22-34*). Both are available with screw pins or round pins.

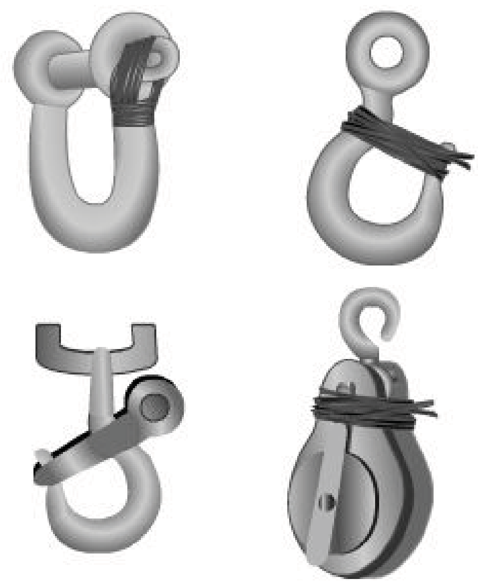


**Figure 22-32 — Mousing.**

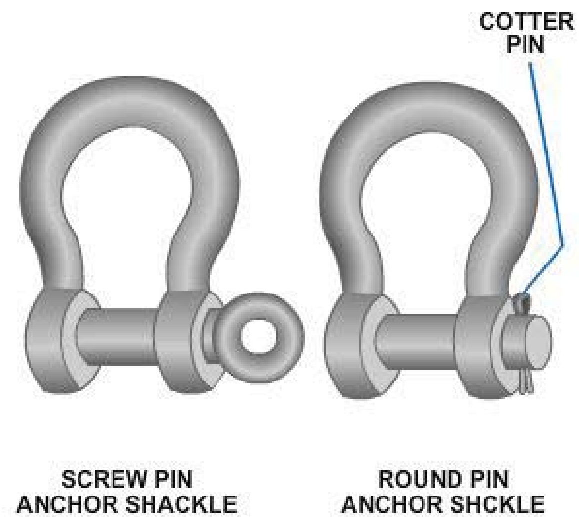



**Figure 22-33 — Anchor shackles.**

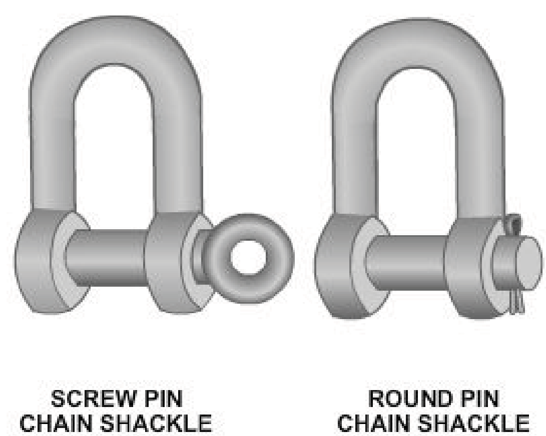



**Figure 22-34 — Chain shackles.**

Use shackles in the same configuration as they were manufactured. NEVER replace the shackle pin with a bolt. When the original pin is lost or does not fit properly, do not use the shackle. All pins must be straight and cotter pins must be used or all screw pins must be seated.

Never pull a shackle from the side, because this causes it to bend, which reduces the capacity tremendously. Always attach a screw pin shackle with the screw pin on the dead end of the rope. If you place it on the running end, the movement of the rope may loosen the pin.

Shackles are moused whenever there is a chance of the shackle pin working loose and coming out because of vibration. To mouse a shackle, simply take several turns with seizing wire through the eye of the pin and around the bow of the shackle. *Figure 22-32* shows what a properly moused shackle looks like.

### 3.12.7 Eyebolts

Eyebolts are often attached to a heavy load by a manufacturer in order to aid in hoisting the load. One type of eyebolt, called a ringbolt, is equipped with an additional movable lifting ring. Eyebolts and ringbolts can be either shoulderless or shoulder type.

The shoulder type is recommended for use in hoisting applications because it can be used with angular lifting pulls, whereas the shoulderless type is designed only for lifting a load vertically. Angular loading reduces the SWL of eyebolts and ringbolts. Always apply loads to the plane of the eye to reduce bending. This procedure is particularly important for using bridle slings.

### 3.12.8 Lifting Lugs

Lifting lugs are typically attached to the object being lifted by a manufacturer. They are designed and located to balance a load and support it safely. Use lifting lugs for straight, vertical lifts only.

### 3.12.9 Turnbuckle

Turnbuckles are used to adjust the length of rigging connections and are available in a variety of sizes. Three common types of turnbuckles are the eye, jaw, and hook ends. They can be used in any combination. The SWL for turnbuckles is based on the diameter of the threaded rods. The SWL can be found in the manufacturer's catalog. The SWL of turnbuckles with hook ends is less than the same size turnbuckle with other types of ends.

### 3.12.10 Beam Clamps

Beam clamps connect hoisting devices to beams so that the beams can be lifted and positioned properly.

### 3.12.11 Plate Clamps

Plate clamps attach to structural steel plates to allow for easier rigging attachment and handling of the plate. There are two basic types of plate clamps: the serrated jaw type, and the screw type.

Serrated clamps are designed to grip a single plate for hoisting and are available with a locking device. Screw clamps are considered the safest and rely on the clamping action of a screw against the plate to secure them. Serrated clamps are for vertical lifting; whereas, screw clamps can be used from a horizontal position through 180 degrees. Plate clamps are designed to lift only one plate at a time.

### 3.12.12 Spreader and Equalizer Beams

Spreader beams are used to support long loads during lifting operations. They eliminate the hazard of load tipping, sliding, or bending. They reduce low sling angles and the tendency of the slings to crush the load.

Equalizer beams are used to balance the load on sling legs and to maintain equal loads on dual hoist lines when making tandem lifts.

## Test your Knowledge (Select the Correct Response)

1. What term is used to describe a wire rope that has strands or wires shaped to conform to the curvature of the finished rope?

   A. Non-preformed wire rope
   B. Preformed wire rope
   C. Non-conform wire rope
   D. Conform wire rope

2. Which part of the following components is part of the construction of a wire rope?

   A. Wires
   B. Strands
   C. Core
   D. All of the above

3. Wire rope is designated by the number of strands per rope and what other factor?

   A. The length of the strand
   B. The diameter of the strand
   C. The number of wires in each strand
   D. The number of strands in each wire

4. Because it is very flexible, which of the following types of wire rope is acceptable for use on cranes?

   A. 6 x 12
   B. 6 x 19
   C. 6 x 24
   D. 6 x 37

# 4.0.0 FIBER ROPE

Fiber ropes are complicated, precision products that are adaptable to many uses under a variety of operating conditions. To meet the requirements which are imposed upon them, ropes are designed and manufactured using a number of different construction techniques and several types of fibers, either natural or synthetic. Large fiber ropes used by the Navy for working operation include those made of manila, nylon, polyester (Dacron), polypropylene, and aramid (Kevlar). Other small cordage used for seizing and lashing consists of sisal, cotton, jute, and hemp.

## 4.1.0 Fiber Rope Identification

### 4.1.1 Fibers

Natural fiber ropes are readily distinguishable from the synthetics by their drier, harsher feel, and their shorter fiber length (24 to 36 inches). Synthetic fibers are usually continuous throughout the length of the rope. Nylon, polyester, multifilament polypropylene, and aramid fibers are very soft and fine, while monofilament and fibrillated film polypropylene fibers are coarse, stiff, and usually brightly colored.

### 4.1.2 Large Ropes

Large ropes are identified by a water-resistant marker inserted into the center of one strand of the rope. When untwisted and flattened, the marker indicates the manufacturer, the date of manufacture, and the fiber type. If these markers are not present, it is necessary to identify the rope fiber content before use. Methods of identification are discussed in the following sections.

### 4.1.3 Manila and Sisal Ropes

Sisal is used in 2-1/2 inch circumference and smaller ropes when the strength of manila is not required. To differentiate between manila and sisal, remove and observe a few fibers from a strand center. Manila fibers will be a light yellow to cream color, with occasional reddish brown tones, whereas sisal will be a lustrous white. If the condition of the rope makes color identification difficult, burn sample fibers on a metal surface. Manila ash will powder during burning, while sisal ash will retain the fiber form. When available, use a known similar fiber as a control.

### 4.1.4 Synthetic Rope

Polypropylene fibers will float in water because the specific gravity of polypropylene is less than the specific gravity of water, which is 1.00. Nylon, polyester, and aramid fibers will sink in water because their specific gravities are greater than 1.00. Nylon and polyester are white; aramid is yellow. To differentiate between nylon and polyester, test burn a sample of the unidentified fiber. A slow-burning blue flame is indicative of nylon, and a fast-burning yellow flame indicates polyester. When available, use a known similar fiber as a control.

## 4.2.0 Fiber Rope Construction

### 4.2.1 Twisted Fiber Ropes

Twisted fiber ropes are constructed of natural or synthetic fibers that are twisted into yarns. In the case of synthetics, three yarns are plied together to prevent the fibers from untwisting. These yarns are then grouped together to form strands, with the size and number of yarns in each strand varying according to the strand size required to make the particular rope size.

### 4.2.2 Large Laid Ropes

All fiber ropes 1-3/4 inch in circumference or larger that the Navy uses are required to be right-laid ropes. This requirement averts hazards of attaching a left-laid rope to a right-laid rope. Under strain, ropes in a left-right combination would unlay each other, resulting in sudden rupture with a load far lighter than the normal maximum limit. Large fiber rope specifications are given in *Table 22-4*.

**Table 22-4 — Fiber Rope Specifications.**

| TYPE OF ROPE | CIRCUMFERENCE (Inches) | SPECIFICATION |
|---|---|---|
| Aramid 4 – Strand | 3 3/8 to 8 3/16 | CID A-A-50435 |
| Polyester Double Braided | 3/4 to 16 | MIL–R-24677 |
| Polyester 12 – Strand | 1 1/8 to 15 | MIL–R-24750 |
| Polyester 8 – Strand Plaited | 3/4 to 16 | MIL–R-24730 |
| Polyester 3 – Strand | 5/8 to 12 | MIL–R-30500 |
| Polyester Double Braided (Staple Wrap) | 3/4 to 5 | MIL–R-24536 |
| Polyester Plaited (Staple Wrap) | 3/4 to 4 1/2 | MIL–R-24537 |
| Nylon Double Braided | 3/4 to 16 | MIL–R-24050 |
| Nylon 8 – Strand Plaited | 3/4 to 16 | MIL–R-24337 |
| Nylon 3 – Strand | 5/18 to 12 | MIL–R-17343 |
| Polypropylene 3 – Strand | 5/18 to 12 | MIL–R-24049 |
| Manila and Sisal | 5/18 to 12 | Fed Spec T-R-605 |

### 4.2.3 Plain Laid Ropes

Plain laid ropes are normally constructed of three strands twisted in an alternate pattern. Natural fiber ropes have a ZSZ twist pattern; the yarn has a right (Z) twist, the strand has a left (S) twist, and the rope has a right (Z) turn. Synthetic fiber ropes have a plied yarn construction with an SZSZ pattern; the single yarns have a left (S) twist, the ply a right (Z) twist, the strand a left (S) twist, and the rope a right (Z) lay. (See *Figure 22-35*). Four strand aramid fiber rope is constructed of parallel yarns in each strand, left laid helically around a strand core. The four parallel laid strands are twisted together in the opposite direction around a center core.

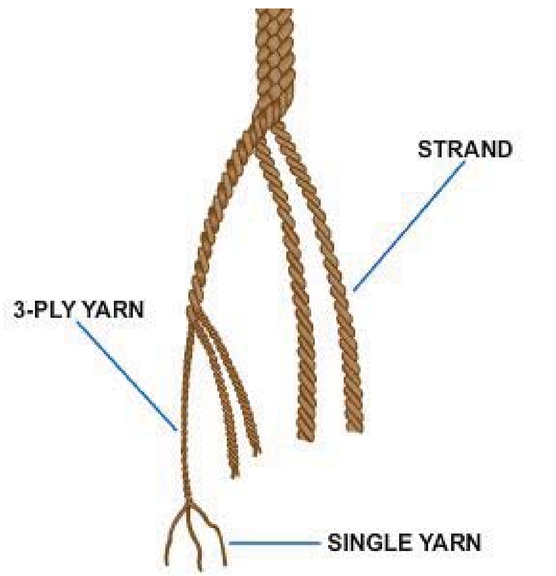



**Figure 22-35 — Synthetic fiber plain laid rope.**

### 4.2.4 Cable Laid Ropes

Cable laid ropes consist of three right plain laid ropes twisted together in the opposite direction (*Figure 22-36*). The final turn in the cable laid rope is always to the left.

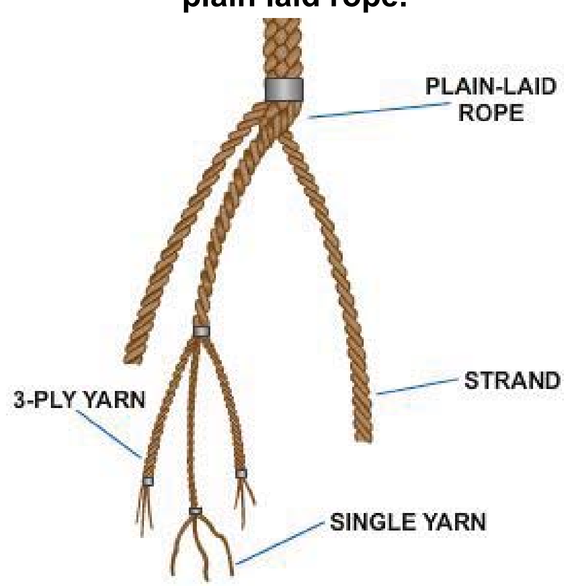



**Figure 22-36 — Synthetic fiber cable laid rope.**

#### 4.2.5 Plaited Ropes

Plaited ropes are available with synthetic fibers. The construction of the strands is similar to three strand synthetic plain laid rope, except there are four right (Z) and four left (S) twist strands. These strands are plaited together in pairs, two parallel strands of left turn going to the right and two parallel strands of right turn going to the left (see *Figure 22-37*). These ropes are available in sizes from 3/4 inch to 16 inches in circumference and are spliceable by cross-braiding of the strands.

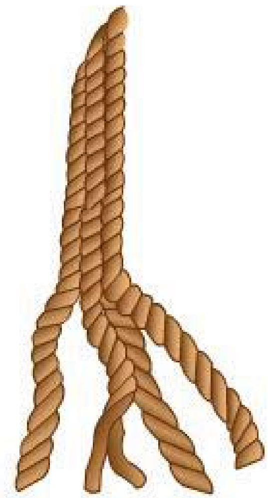



**Figure 22-37 — Plaited rope.**

#### 4.2.6 Braided Ropes

Braided ropes have been reclassified from special to general purpose use. There are several different types of braided ropes: namely, hollow braid, stuffer braid, solid braid, and double braid. With the exception of double braid, braided ropes range in sizes up to 1 inch circumference. Double braided ropes are available up to 16 inches in circumference. The chief advantage of double braided rope is that it can be made in long continuous lengths (up to 20,000 feet) without noticeable splice bulge, and it will not kink or twist in a single part operation while under load.

### 4.3.0 Precautions and Techniques for the Use of Ropes

#### 4.3.1 Uncoiling Natural Fiber Laid Ropes

If natural fiber ropes are furnished in coils, uncoil them by drawing the rope up from the eye in a counterclockwise direction to avoid rope kinking. Should kinks develop as a result of improper uncoiling, DO NOT pull them out as they develop into permanent strand cockles and reduce the rope strength by 1/3. When kinks develop, lay the rope out straight and remove the unbalanced turn before use. Fake down ropes that are to be used in blocks and falls and allow them to relax for at least 24 hours before reeving. After reeving, tension the completed tackle under a load equal to 1/10 of the total strength of the number of parts making up the falls.

#### 4.3.2 Uncoiling Synthetic Fiber Laid Ropes

If synthetic fiber ropes are furnished in coils, uncoil them by rolling or by drawing from a turntable. DO NOT attempt to draw up through the eye or from the outer flakes of the coil. Should a coil of synthetic fiber rope collapse, causing kinking and tangling, DO NOT try to pull the rope free as it will form permanent cockles.

#### 4.3.3 Unreeling Synthetic Fiber Ropes

When synthetic fiber ropes are unreeled, insert a pipe mandrel through the center holes of the reel heads to hold the reel clear of the deck. The rope may then be drawn from the lower reel surface with no danger and without rope damage. DO NOT throw twisted synthetic fiber ropes off reel heads, as tangles and kinks will develop. It is also recommended that new, twisted synthetic fiber ropes be faked down on the deck and allowed to relax for 24 hours. Lengths of new twisted synthetic fiber ropes less than 50 feet long will relax within 1 hour when laid out straight. Fake down double braided rope in a figure-eight pattern. If double braided rope is faked down in the same fashion as described for twisted rope, it will develop twists.

## 4.4.0 Recoiling and Rereeling

Recoil or Flemish all twisted ropes in the clockwise direction. Rereeling may be done in either direction, but take care that the turns are laid closely together to prevent binding in the underturns.

## 4.5.0 Elongation and Permanent Stretch

### 4.5.1 Natural Fiber Ropes

Load stretching is permanent and irreversible in natural fiber ropes such as manila and sisal. With each successive load increase, an additional amount of permanent stretch occurs until the stretch limit is reached and the rope fails. The stretch limit for a natural fiber rope is approximately 20 percent of its original length; for example, a 10 foot length of rope will break when it reaches its stretch limit at 12 feet.

### 4.5.2 Synthetic Fiber Ropes

A portion of the load-stretch in synthetic fiber ropes is permanent and irreversible. However, this permanent stretch is small and not progressive with successive loadings, provided those loadings do not exceed SWLs. Under safe load conditions, the permanent stretch of nylon and polyester ropes is usually no greater than 7 percent of the original length; aramid is much less. After a synthetic fiber rope has reached its maximum stretch point (usually at the fifth loading), it will stretch and recover repeatedly without serious damage. The approximate stretch limits (at breaking strength) for synthetic fiber ropes vary widely: only 6 percent for aramid 4-strand; 30 percent for polyester double braid and polyester 12-strand; 35 percent for polyester 3-strand; 40 percent for nylon double braid; 45 percent for polyester 8-strand plaited and polypropylene 3-strand; 55 percent for nylon 3-strand; and 65 percent for nylon 8-strand plaited.

## 4.6.0 Shrinkage and Swelling

Most natural and synthetic fiber ropes, when wet, will shrink in length and swell in diameter to some extent. The shrinking and swelling do not seriously affect rope strength, but stiffness which occurs after drying out will cause some difficulty in splicing.

### 4.6.1 Natural Fiber Ropes

Wet conditions cause natural fiber ropes to shrink and swell. Shrinkage varies with rope size, ranging from 5 to 8 percent, with a corresponding amount of swelling and stiffening. After drying, natural fiber ropes remain in the shrunken state. Rope in this condition is not weakened, but does kink more easily; therefore, rouse out the rope from lockers or coils with care.

### 4.6.2 Synthetic Fiber Ropes

Synthetic ropes shrink slightly when wet, and minimal swelling may occur. The only noticeable effect of wet conditions is a slight increase in weight, with the exception of nylon which has approximately 15 percent strength loss from water being absorbed by the nylon molecules. (Nylon regains most of this strength loss if dried out.) Absorbed water will be squeezed out when the ropes are tensioned. Under working loads, the expelled water will appear as a steamlike water vapor. This vapor is beneficial because it cools the fibers when friction develops under repeated stretching conditions, as in towing.

## 4.7.0 Whipping and Sealing

### 4.7.1 Whipping

Whipping natural fiber rope ends is similar to seizing, but is done to prevent rope ends from fraying and unlaying.

### 4.7.2 Sealing

Heat-sealing the ends of synthetic rope is especially effective and will prevent sewed whippings from slipping off. This procedure consists of placing whipping around the rope, cutting off excess yarns, and then sealing the rope ends by pressing them against a hot metal surface or by applying heat from a torch.

## 4.8.0 Extending Rope's Service Life

The safety of personnel and equipment and the performance of many important construction projects depend upon correct use and maintenance of ropes. All personnel are held responsible for protecting ropes from damage and for a thorough knowledge of the effects of age and working conditions on rope selection and performance.

### 4.8.1 Damaging Conditions

#### 4.8.1.1 Excessive Pull

Avoiding excessive tension (overloading of the rope) requires knowledge of the recommended SWL, the minimum breaking strength, and the elongation (stretch) of the rope. Apply the load slowly and carefully using a tattle-tale while noting the reduction in circumference and increase in length to avoid excessive tension. Tattle-tales cannot be used with aramid lines, because aramid lines have low stretch (comparable to wire rope); also, they do not neck-down (reduce circumference) appreciably when put under load. Carefully control the load to avoid excessive tension (overloading of the line).

#### 4.8.1.2 Surface Abrasion

Rope surface abrasion and chafing are serious concerns, particularly for polypropylene and manila ropes, which have a high coefficient of friction with structural materials. Nylon and polyester ropes are less affected by abrasion and chafing, as is aramid rope, which has a braided cover on each strand, but each should be protected to ensure longer service life.

#### 4.8.1.3 Gritty Material

A variety of gritty materials, ranging from hard crystalline sands to flaky graphite, can seriously damage fiber rope when they become lodged between the rope yarns and strands while the rope is in a relaxed state. When loads are later applied to the ropes, the grit works progressively outward, cutting the inner fibers and destroying the rope structure.

#### 4.8.1.4 Effects of a Freezing Environment

Although not always recognized as such, frozen water (ice) is another abrasive that can cut fibers under tension. Wet natural and synthetic fiber ropes that are allowed to freeze are therefore reduced in strength. Although bending will cause the external ice coating to fall away, ice crystals that remain within the rope yarns and strands will fracture the inner fibers and result in rope failure when tension is applied to the rope. Allow frozen ropes to thaw thoroughly and drain before use. Store fiber ropes under cover to prevent ice crystal formation. Nylon, polyester and aramid ropes should be wound tightly on reels and covered when dry.

#### 4.8.1.5 Sharp Edges and Shearing

To prevent rope damage, use padding or fairleads on sharp metal edges of parts such as coamings, fairwater guides, metal block cheeks, and padeyes, or, if practical, relocate or modify the parts.

Another type of mechanical damage is the shearing action caused by crushing or pinching. Such damage often occurs when a kink in the rope is permitted to run into a block and bind against the cheeks. Other crushing effects are caused by knots in the rope or by hauling heavy loads over the rope. Shearing can be readily avoided by careful attention to receiving and handling procedures.

## 4.9.0 Effect of Aging on Fiber Ropes

### 4.9.1 Natural Fiber Ropes

Natural rope fibers (manila and sisal) consist mainly of cellulose and have the same aging properties as paper. They become yellow or brownish and brittle with time, even under the best storage conditions. This color change indicates some loss of strength, usually from 1 to 2 percent loss per year of storage. However, strength loss alone is not a true index of rope deterioration because the rope fibers become so stiff and brittle with age that when ropes are bent over sheaves or other holding devices, the fibers rupture easily and break down further with each successive bend, even under light loading conditions. Rope bending strength loss is more significant than rope breaking strength loss because the bending strength decreases five times more rapidly. Because of this, it is important to determine the age of unused natural fiber ropes from the identification marker tape within the rope strand. Should the marker indicate the age to be 5 years or more, do not use the rope for critical operations or those involving the lives of personnel.

### 4.9.2 Synthetic Fiber Ropes

Although synthetic fiber ropes also show color change with aging, this color change does not indicate a change in strength. White nylon ropes develop a lemon-yellow or pink color and become stiff when stored in a warm, humid area. At first the stiffness will present some handling difficulty, but when tensioned, white nylon ropes will become flexible with no breaking or bending strength loss. Polyester ropes lose very little strength due to exposure and tend to take on a gray cast. Unstabilized polyethylene and polypropylene ropes will deteriorate very rapidly when exposed to sunlight on a continuing basis and could easily lose 40 percent of their strength over a 3 month exposure period. Avoid the use of polyolefin ropes (polyethylene or polypropylene) where prolonged exposure to sunlight is required.

## 4.10.0 Rope Stowage

### 4.10.1 Natural Fiber Rope Stowage

Ropes of manila, sisal, and other natural fibers are subject to deterioration from heat, sunlight, and mildew rot. They are also damaged by chemicals, acids, alkalies, paints, soaps, and vegetable oils such as linseed or cottonseed. It is therefore mandatory that natural fiber ropes be stored away from any of these damaging materials or conditions. The best storage for natural fiber ropes is a dry, cool, dark, well-ventilated area, far removed from any source of chemicals or gaseous fumes. If natural fiber ropes are stowed outside, hang them on reels or pegs and cover them with weatherproof materials.

### 4.10.2 Synthetic Fiber Rope Stowage

Synthetic fiber ropes are usually packaged on reels and covered with waterproof paper to prevent damage in transit or storage. If covers or reels are damaged during prolonged storage, repair the reels and promptly replace the paper covering to prevent exposure, because most synthetic fiber ropes are affected by sunlight, fluorescent light, and chemicals. Nylon ropes are sensitive to all light radiations and acid chemicals; polyester ropes are sensitive to sunlight and caustic (alkaline) chemicals.

## 4.11.0 Inspection Criteria

When inspecting natural or synthetic fiber ropes, look for indications of rope damage as follows:

1. When inspection reveals fiber rupture and powdering between strands, the rope has been overloaded and rendered unfit for service.
2. If there are dark red, brown, or black spots between the strands or if it has a sour, musty, or acidic odor, the rope has suffered considerable damage from rot and shall be destroyed. Storage of rotting rope adjacent to new rope will promote rapid infection of the new rope. Remove both ropes so stored; dry and air the area before restorage of the new rope.
3. Cut out distorted strand areas because they reduce rope strength by as much as 60 percent. These defects are the result of improper coiling and bending operations and can be avoided by strictly observing approved rope coiling, bending, and unkinking procedures.
4. Internal wear is detected as a powdery appearance between the natural fiber rope strands and by a fuzzed or fused condition between synthetic rope strands.
5. Frequently examine ropes in service in areas where chemicals (acids or akalies) are used for evidence of chemical damage such as brittle or ruptured fibers, dark red or brown spots, salt incrustation, and swollen areas. Remove from service any rope showing signs of such damage.
6. Inspect ropes used in tackle operations for localized rust spots; pay particular attention to ropes used in exterior marine areas where iron rusting promotes rope deterioration.
7. Do NOT use natural fiber ropes of indeterminate age in any critical application.
8. A harsh, dry, dead feel in manila or sisal rope indicates doubtful quality and precludes rope use.

9. Hand pull tests of single or small rope fiber bundles can indicate the quality of the rope from which they were removed. A strong fiber will usually cut into the flesh, leaving a red mark, and will emit a sharp cracking noise upon breaking. Weakened fiber will not mark the flesh and will break with a soft popping sound.
10. Accumulation of heavy, greasy materials adversely affects rope strength and reduces holding power. Remove greasy materials by rinsing with light petroleum fuels such as diesel oil or kerosene.
11. Measure ropes that are to be end for ended for sheave fit to ensure that the unworked end has not swollen to the point that it will chafe on the block cheeks. If the end does not fit into the sheave, cut away the swollen section before reeving.
12. When 30 percent of the yarns in a rope cross section have been worn through, remove the rope from working operations.

## 4.12.0 Synthetic Ropes

### 4.12.1 Advantages

Numerous laboratory and service tests have determined that synthetic fiber ropes are 1-1/2 to over 4 times as strong as manila ropes of equal size. Their superior strength and durability, with good working elongations (except for aramid), make these ropes very desirable for many applications involving heavy loads. Synthetic rope resistance to rot and mildew contributes to longer rope life. Reduced bulk and weight are other advantages offered by synthetic fiber ropes. The increasing use of synthetic ropes makes it essential that all rope handling personnel be familiar with the properties of this type of rope, since these properties differ from those of manila rope. Pay particular attention to the precautions for using synthetic fiber ropes.

### 4.12.2 Maintenance

Synthetic fiber ropes soon fluff or nap as a result of small surface filament abrasion. The strength loss is negligible, except in the case of monofilament polypropylene ropes, which behave in the same manner as natural fiber ropes. In fact, most synthetic ropes will hold a load despite extensive yarn abrasion. If a localized, badly chafed section develops, cut out that section and splice the ends together for satisfactory continued use. Surface abrasion and stretching are not necessarily indicative of reduced rope load-carrying ability, because synthetics have little internal abrasion and little permanent stretch.

Rusting can cause a 40 percent loss of nylon rope breaking strength in only 1 month. Accordingly, avoid prolonged rope contact with rust-prone bare iron surfaces unless such surfaces have protective rust-proof coatings, such as anti-corrosive epoxy or silicone alkyd or latex-base paints. Wood, aluminum, and bronze surfaces have no effect on synthetic fiber ropes.

# 5.0.0 CHAINS

In the NCF, never use a chain when it is possible to use wire rope. The reason for this is that unlike wire rope, chain does not have reserve strength and does not give any warning that it is about to fail; therefore, you will not be alerted of a potentially hazardous condition.

Chain is better suited than wire rope for some jobs because it is more resistant to abrasion, corrosion, and heat. When chain is used as a sling, it has no flexibility and grips the load well.

## 5.1.0 Chain Grades

It is difficult to determine the grade of some types of chains by looking at them. Most chains used by the NCF are class A, alloy steel chain grade 80 or grade 100. If you are uncertain of the class or size of a chain, ask your supervisor.

## 5.2.0 Chain Strength

Before lifting with a chain, make sure the chain is free from twists and kinks. A twisted or kinked chain placed under stress could fail even when handling a light load. Additionally, ensure that the load is properly seated in the hook (not on the point) and that the chain is free from nicks or other damage. Avoid sudden jerks in lifting and lowering the load, and always consider the angle of lift with a sling chain bridle.

The strength of any chain will be affected when it has been knotted, overloaded, or heated to temperatures above 500°F.

## 5.3.0 Chain Handling and Care

When hoisting heavy metal objects using chain for slings, insert padding around the sharp corners of the load to protect the chain links from cuts.

Store chains in a clean, dry place, protected from weather. Before storing, apply a light coat of lubricant to prevent rust.

Do NOT perform makeshift repairs, such as fastening links of a chain together with bolts or wire. When links become worn or damaged, cut them out of the chain, then fasten the two nearby links together with a connecting link. For cutting small sized chain links, use bolt cutters. To cut large sized links, use a hacksaw.

Inspect the chain to ensure a safe operating condition. Frequently inspect chains used continuously for heavy loading. Chains are less reliable than manila or wire rope slings because the links have the potential to crystallize and snap without warning.

Before lifting with a chain, first place dunnage between the chain and the load to provide a gripping surface. For hoisting heavy metal objects with a chain, always use chafing gear around the sharp corners on the load to protect the chain links from being cut. As chafing gear, use either planks or heavy fabric. In handling rails or a number of lengths of pipe, make a round turn and place the hook around the chain (*Figure 22-38*).

Examine the chain closely link by link and look for stretch, wear, distortion, cracks, nicks, and gouges. Wear typically appears at the ends of the links where joining links rub together. If you find wear, lift each link

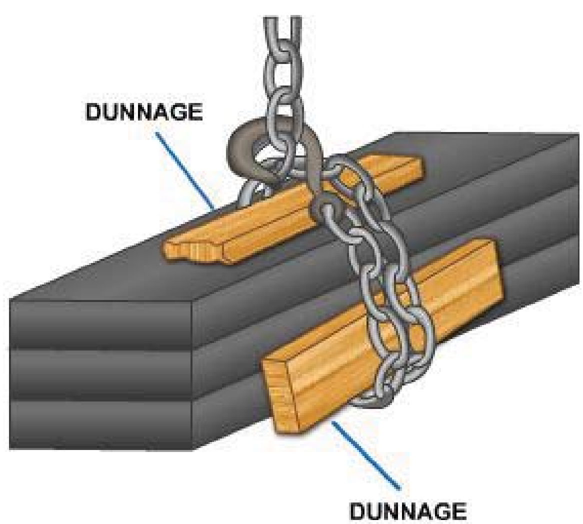



**Figure 22-38 — Chain sling with chafing gear.**

and measure its cross section. Refer to *Table 22-5.*

**Table 22-5 — Minimum Allowable Thickness of Chain Sling Link**

| Nominal Size of Link (Inches) | Minimum Allowable Thickness (Inches) |
|---|---|
| 7/32 | 0.189 |
| 9/32 | 0.239 |
| 5/16 | 0.273 |
| 3/8 | 0.342 |
| 1/2 | 0.443 |
| 5/8 | 0.546 |
| 3/4 | 0.687 |
| 7/8 | 0.750 |
| 1 | 0.887 |
| 1 1/4 | 1.091 |
| 1 3/8 | 1.187 |
| 1 1/2 | 1.261 |

## 5.4.0 Chain Sling Rejection Criteria

Remove the sling from service if inspection reveals any of the following:

- Reduction of link size below the values specified in *Table 22-5* or as limited by the OEM if more restrictive. For sizes not shown consult the OEM.
- Missing or illegible sling identification
- Cracks or breaks
- Excessive wear, nicks, or gouges
- Stretched chain links or components
- Bent, twisted, or deformed chain links or components
- Evidence of heat damage
- Excessive pitting or corrosion
- Weld splatter
- Knots in any part of sling

Before lifting with a chain, first place dunnage between the chain and the load to provide a gripping surface. For hoisting heavy metal objects with a chain, always use chafing gear around the sharp corners on the load to protect the chain links from being cut. As chafing gear, use either planks or heavy fabric. In handling rails or a number of lengths of pipe, make a round turn and place the hook around the chain (*Figure 22-11*).

## Test your Knowledge (Select the Correct Response)

5. For some jobs, which of the following properties make chain more suited for use than wire rope?

   A. Resistant to abrasion
   B. Resistant to corrosion
   C. Resistant to heat
   D. All of the above

# 6.0.0 SLINGS

Slings are widely used for hoisting and moving heavy loads. Some types of slings come already made. Slings may be made of wire rope, fiber line, or chain.

## 6.1.0 Slings and Rigging Gear Types

The Naval Construction Force (NCF) has slings and rigging gear in the battalion Table of Allowance (TOA) to support the rigging operations and CESE lifting. Kit types 80098B, 80104B, 80104, 84003, and 84004 remain in the custody of the supply officer in the Central Tool Room (CTR). The designated embarkation staff and the crane test director monitor the condition of all rigging gear. The crane crew supervisor normally has the responsibility of inventorying the kit contents. The rigging kits must be stored under cover.

### 6.1.1 Wire Rope Slings

Wire rope slings offer the advantages of both strength and flexibility. These qualities make wire rope adequate to meet the requirements of most crane hoisting jobs; therefore, wire rope slings are used more often than fiber line or chain slings.

### 6.1.2 Fiber Line Slings

Fiber line slings are flexible and protect finished material better than wire rope slings. However, fiber line slings are not as strong as wire rope or chain slings and are more likely to be damaged by sharp edges.

### 6.1.3 Chain Slings

Chain slings are most often used for hoisting heavy steel items, such as rails, pipes, beams, and angles. Chain slings are the most appropriate type of sling for hot loads and loads that have sharp edges that might otherwise sever the sling components.

## 6.2.0 Using Wire Rope and Fiber Line Slings

There are three types of wire rope and fiber line slings: endless, single leg, and bridle.

An endless sling, usually referred to as a sling, can be made by splicing the ends of a piece of fiber line or wire rope to form an endless loop. An endless sling is easy to handle and can be used as a choker hitch (*Figure 22-39*). A single-leg sling, commonly referred to as a strap, can be made by forming a spliced eye in each end of a piece of fiber line or wire rope. Sometimes the ends of a piece of wire rope are spliced into eyes


**Figure 22-39 – Endless slings.**

around thimbles, and one eye is fastened to a hook with a shackle. In this arrangement, the shackle and hook are both removable.

The single-leg sling may be used as a choker hitch (Refer to *Figure 22-39*) in hoisting by passing one eye through the other eye and over the hoisting hook. The singe-leg sling is also useful as a double-anchor hitch (See *Figure 22-39*), and works well for hoisting drums or other cylindrical objects where a sling must tighten itself under strain and lift by friction against the sides of the object. Single-leg slings are used to make various types of bridles.

Single-leg slings can be used to make various types of bridles. Three common uses of bridles are shown in *Figure 22-40*. Two or more single slings may be used for a given combination.

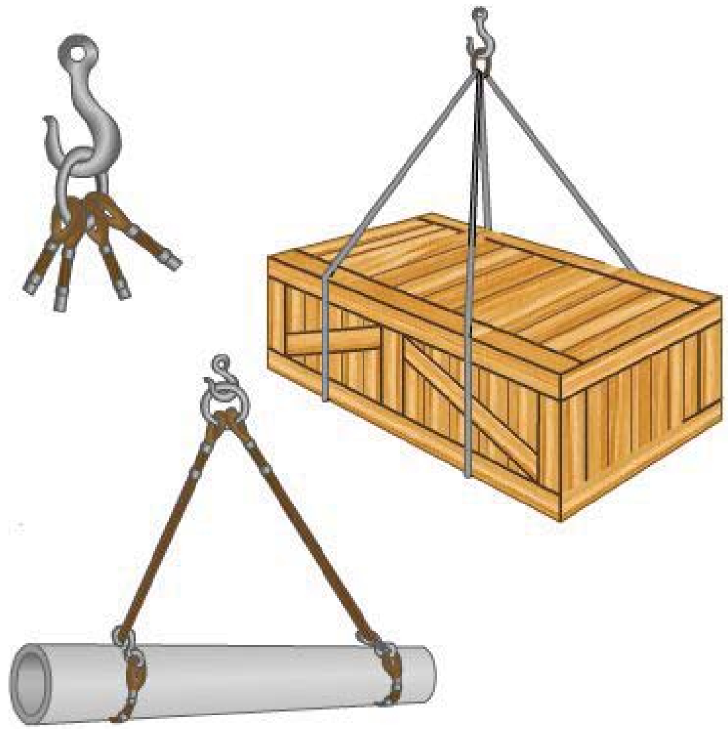


Figure 22-40 — Multi-legged bridle slings.

The bridle hitch provides excellent load stability when the load is distributed equally among each sling leg. The load hook is directly over the center of gravity of the load, and the load is raised level. The use of bridle slings requires that the sling angles be carefully determined to ensure that the individual legs are not overloaded.

**NOTE**

It is wrong to conclude that a three or four leg bridle will safely lift a load equal to the safe load on one leg multiplied by the number of legs. This is because there is no way of knowing whether each leg is carrying its share of the load.

When a four-legged bridle sling lifts a rigid load, it is possible for two of the legs to support practically the full load, while the other two legs only balance it. NAVFAC P-307 strongly recommends that the rated capacity for two-legged bridle slings listed in the NAVFAC P-307 be used as the safe working load for three and four-legged bridle hitches.

When lifting heavy loads, ensure that the bottom of the sling legs are fastened to the load in an effort to prevent damage to the load. Many pieces of equipment have eyes fastened to them during the process of manufacture to aid in lifting. With some loads, though, fastening a hook to the eye on one end of each sling leg suffices to secure the sling to the load.

Use a protective pad to protect a fiber line or wire rope sling from exposure to sharp edges at the corner of the load. Pieces of wood or old rubber tires are often available and handy for padding.

### 6.2.1 Sling Angles

When using slings, bear in mind that the greater the angle from the vertical, the greater the stress on the sling legs. This point is shown in *Figure 22-41*.

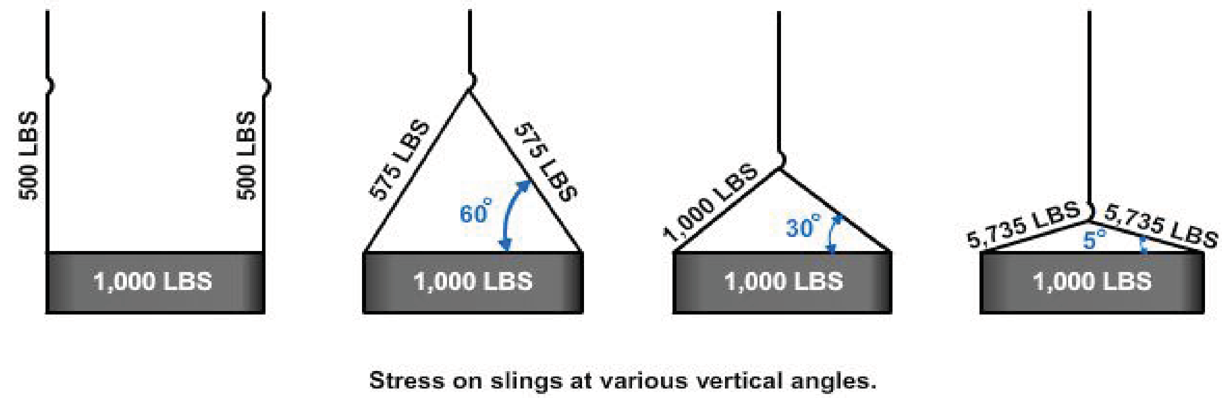



**Figure 22-41 – Stress on slings at various vertical angles.**

The rated capacity of any sling depends on its size, the configuration of its legs, and the angles formed by the legs and the horizontal. A sling with two legs used to lift a 1,000 pound object has 500 pounds of the load on each leg when the sling angle is 90 degrees. The load stress on each leg increases as the angle decreases; for example, if the sling angle is 30 degrees when lifting the same 1000 pound object, the load is 1000 pounds on each leg. Try to keep all sling angles greater than 45 degrees; sling angles approaching 30 degrees are considered extremely hazardous.

### 6.2.2 Spreader Bars

In hoisting with slings, spreader bars are used to prevent crushing and damaging the load. Spreader bars are short bars, or pipes, with eyes fastened to each end. By setting spreader bars in the sling legs above the top of the load (*Figure 22-42*), you change the angle of the sling leg and avoid crushing the load, particularly in the upper portion.

Spreader bars are also used in lifting long or oversized objects to control the sling angle. When you use spreader bars, make sure you do not overload the end connection. A spreader bar has the same rated capacity as hooks and shackles. A good rule of thumb is the thickness of the spreaders' end connection should be the same as the thickness of the shackle pin.

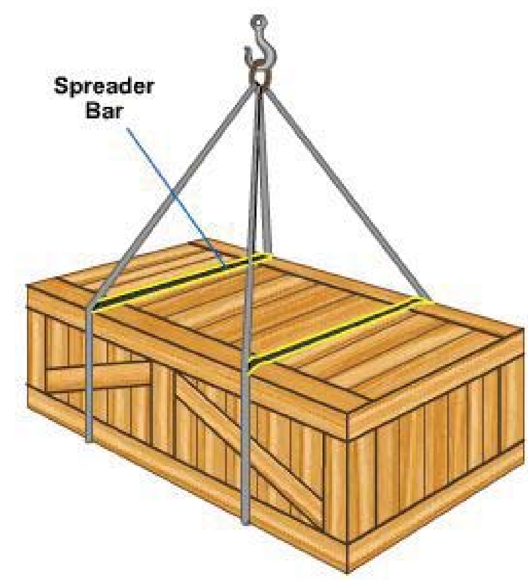



**Figure 22-42 — Using spreader bars.**

### 6.2.3 Sling Safe Working Loads

There are several formulas for estimating the loads for most sling configurations. These formulas are based on the SWLs of the single-vertical hitch of a particular sling. When determining the capacity of the combination, consider the efficiencies of the end fittings used.

The formula used to compute the SWL for a bridle hitch with two, three, or four legs (*Figure 22-43*) is: SWL (of single-vertical hitch) x Height (H) divided by Length (L) x 2. When the sling legs are not equal in length, used the smallest H/L measurement. This formula is intended for a two-leg bridle hitch, but should be used for a three or four leg hitch as well.

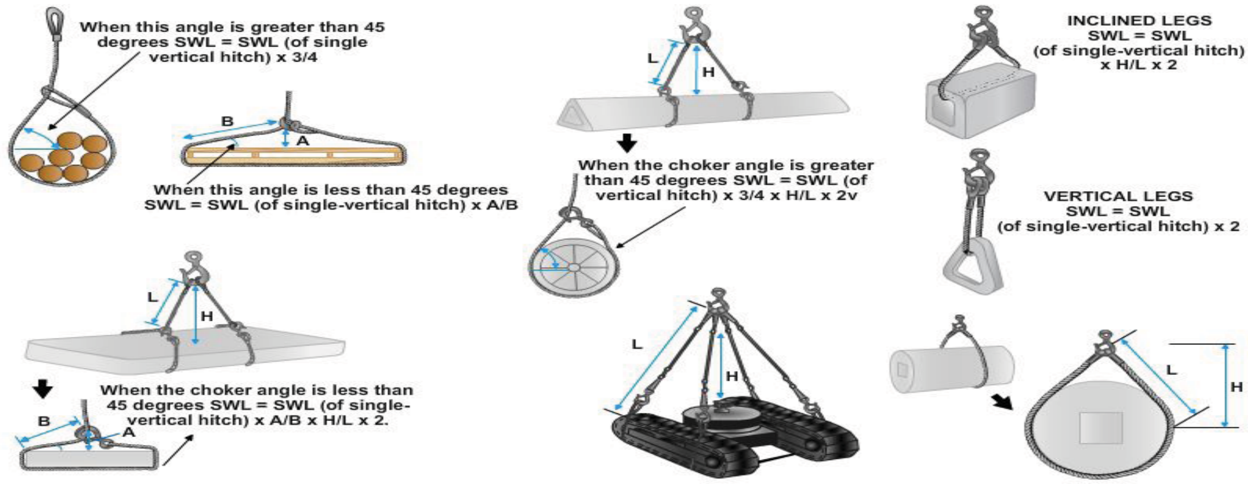



**Figure 22-43 – Determination of various sling capacities.**

**NOTE**

Remember: It is dangerous to assume that a three or four-leg hitch can safely lift a load equal to the safe load on one leg multiplied by the number of legs.

Other formulas include:

- Single-Basket Hitch (for vertical legs): SWL (of single vertical hitch) x 2
- Single-Basket Hitch (for inclined legs)**:** SWL (of single vertical hitch) x H divided by L x 4
- Double-Basket Hitch (for vertical legs): SWL (of single vertical hitch) x 4
- Double-Basket Hitch (with inclined legs): SWL (of single vertical hitch) x H divided by L x 4
- Single-Choker Hitch (for sling angles of 45 degrees or more)**:** SWL (of single vertical hitch x 3/4 or .75
- Single-Choker Hitch (for sling angles of less than 45 degrees)**:** Remember, this is not recommended, and may compromise the integrity of the load and the safety of personnel. SWL (of single vertical hitch x Adivided byB)
- Double-Choker Hitch (for a single angle of 45 degrees or more): SWL (of single vertical hitch) x 3 divided by 4 x H divided by L x 2
- Double-Choker Hitch (for a single angle of less than 45 degrees): SWL (of single vertical hitch) x A divided by B x H divided by L x 2

### 6.2.4 Sling Inspection

Visually inspect all slings for obvious unsafe conditions before each use. A determination to remove slings from service requires experience and good judgment, especially when evaluating the remaining strength in a sling after allowing for normal wear. The safety of the sling depends primarily upon the remaining strength. Wire rope slings must be immediately removed from service if any of these conditions are present:

- Six randomly distributed broken wires in one rope lay or three broken wires in one strand in one lay
- Wear or scraping on one third of the original diameter of the outside individual wires
- Kinking, crushing, bird caging, or any other damage resulting in distortion of the wire rope structure
- Evidence of heat damage
- End attachments that are cracked, deformed, or worn
- Hooks that have obviously abnormal (usually 15 percent from the original specification) throat opening, measured at the narrowest point or twisted more than ten degrees from the plane of the unbent hook
- Corrosion of the wire rope sling or end attachments

To avoid confusion and eliminate doubt, do not downgrade slings to a lower rate capacity. Remove a sling from service if it cannot safely lift the load capacity for which it was originally rated. Destroy slings and hooks removed from service by cutting before disposal to ensure they will not be used again.

When a leg on a multiple-leg bridle sling is unsafe, it is necessary only to destroy the damaged or unsafe leg(s). Units that have the capability may fabricate replacement legs in the field, provided the wire rope replacement is in compliance with specifications. The NCF has a hydraulic swaging and slicing kit in the battalion TOA. Before use, all slings must be proof tested in accordance with NAVFAC P-307.

Spreader bars, shackles, hooks must also be visually inspected before each use for obvious damage or deformation.

Check fiber line slings for signs of deterioration caused by weather exposure. Ensure that no fibers have been broken or cut by sharp-edged objects.

### 6.2.5 Proof Testing Slings

Proof load all field fabricated slings terminated by mechanical splices, sockets, and pressed and swaged terminals before they are placed into initial service. NAVFAC P-307 has the rated capacity charts that describe the diameter, rope construction, type core, grade, and splice on the wire rope sling as well as vertical rated capacity V.R.C.) for the sling. The test weight for single leg bridle slings and endless slings is the V.R.C. times two (V.R.C. x 2 = sling test weight).

Applyl the test load for multiple leg bridle slings to the individual legs. Be sure the load is two times the V.R.C. of a single leg sling of the same size, grade, and wire rope construction. When slings and rigging are broken out of the TOA for field use, proof-test and tag them before returning them to CTR for storage.

### 6.2.6 Records

The crane crew supervisor establishes and maintains a card file system containing a record of each sling in the unit's inventory. Proof Test/Inspection Sheets (*Figure 22-44*) are used to document tests made on all items of weight lifting slings, spreader bars, hooks, shackles.

Card _____ of _____

WIRE ROPE SLING PROOF TEST/INSPECTION RECORD

SAMPLE

Specifications: ____________________

Length: ____________________

Cable body diameter: ____________________

Type splice: ____________________

Rated capacity (lbs): ____________________

* Proof test weight (lbs): ____________________

* Date of proof test: ____________ Proof test director sig: ____________

Date of inspection: ____________ Crane Uspv inspector sig: ____________

Date of inspection: ____________ Crane Supv inspector sig: ____________

Date of inspection: ____________ Crane Supv inspector sig: ____________

REMARKS:

*Applies only to field fabricated slings.

____________ DATE

____________ SLING ID NO.

**Figure 22-44 – Proof test/inspection sheet.**

These records are permanent and contain at a minimum:

- Sling identification number (unit location and two digit number with Alpha designation for each wire rope component)
- Sling length
- Cable body diameter (inches) and specifications
- Type of splice
- Rated capacity
- Proof test weight
- Date of proof test
- Signature of proof test director

All the slings must have a permanently affixed, near the sling eye, durable identification tag containing:

- Rated capacity (in tons) (vertical SWL)
- Rated capacity (in tons) (45 degree SWL)
- Identification number

Spreader bars, shackles, and hooks must have their rated capacities and SWL permanently stenciled or stamped on them. Occupational Safety and Health Administration (OSHA) identification tags can be acquired at no cost from CONTHIRDNCB DET, Port Huenemie, CA or COMSECONDNCB DET, Gulf Port, MS. Metal dog tags are authorized, providing the required information is stamped onto the tags.

### 6.2.7 Storage

Wire rope slings and associated hardware must be stored in either coils or on reels, hung in the rigging loft, or laid on racks indoors to protect them from corrosive weather and other types of damage such as kinking or being backed over. Do NOT leave slings on the crane at the end of the work day.

## Test your Knowledge (Select the Correct Response)

6. In the NCF, at what location are the 80104, 84003, and 84004 kits maintained?

   A. Collateral equipage
   B. Central Tool Room
   C. Mechanic shop
   D. Rigging loft

7. The bridle hitch provides excellent load stability when which of the following conditions exists?

   A. The load is distributed equally among each sling leg
   B. The load hook is directly over the center of gravity of the load
   C. The load is raised level
   D. All of the above

8. **(True or False)** A three or four leg hitch can safely lift a load equal to the safe load on one leg multiplied by the number of legs.

   A. True
   B. False

# 7.0.0 MECHANICAL ADVANTAGE

The push or pull a human exerts depends on the weight and strength of the individual. To move any load heavier than the amount a person can physically move, a mechanical advantage must be used to multiply human physical power. The mechanical devices most commonly used for this purpose are block and tackles, chain hoists, and winches.

## 7.1.0 Block and Tackle

A block consists of one or more sheaves fitted in a wood or metal frame supported by a shackle inserted in the strap of the block. A tackle is an assembly of blocks and lines used to gain a mechanical advantage in lifting and pulling.

The block(s) in a tackle assembly change(s) the direction of the pull, provide(s) mechanical advantage, or both. The name and location of the key parts of a fiber line block (*Figure 22-45*) include:

- Frame (or shell): Houses the sheaves and is made of wood or metal

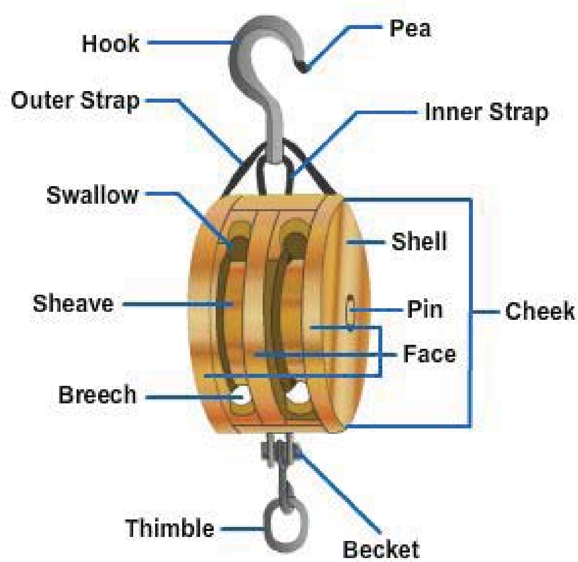



**Figure 22-45 — Parts of a fiber line block.**

- Sheave: A round, grooved wheel over which the line runs. Usually the blocks have anywhere from one to four sheaves. Some blocks have up to eleven sheaves.
- Cheeks: The solid sides of the frame or shell
- Pin: A metal axle on which the sheave turns. The pin runs from cheek to cheek through the middle of the sheave.
- Becket: A metal loop formed at one or both ends of a block. The standing part of the line is fastened to the becket.
- Straps: Hold the block together and support the pin on which the sheaves rotate
- Shallow: The opening in the block through which the line passes

In a tackle assembly, (*Figure 22-46*) the line is passed over the sheaves of blocks. The two types of tackle systems are simple and compound. A simple tackle system is an assembly of blocks with a single line. A compound tackle system is an assembly of blocks with more than one line.

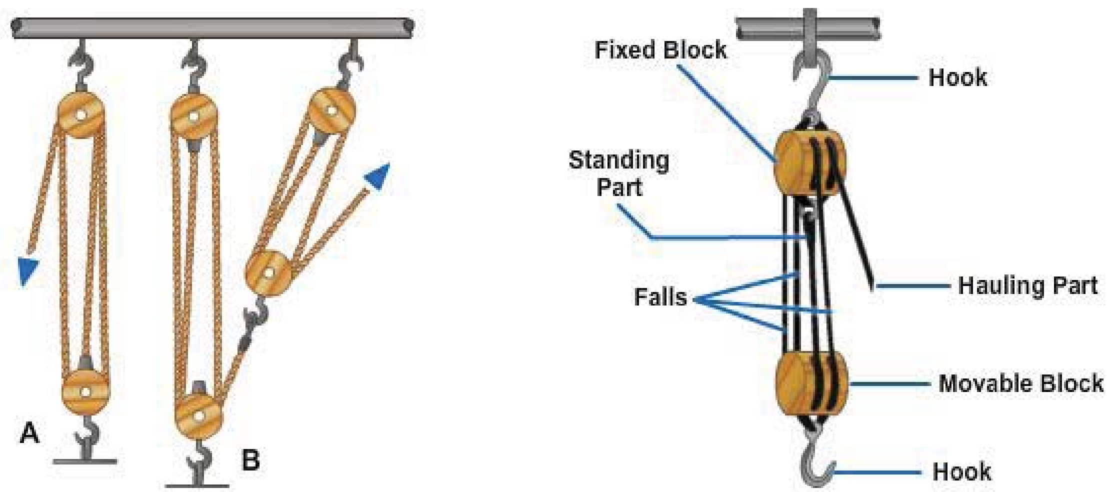



**Figure 22-46 — Simple and compound tackle, as well as components of tackle.**

Tackle related terminology includes:

- Fall: Either the wire rope or fiber line reeved through a pair of blocks to form a tackle
- Hauling part: Leads from the block upon which the power is exerted
- Standing: the end attached to a becket
- Movable (or running) bock: The block attached to a fixed objector support. When a tackle is being used, the movable block moves and the fixed block remains stationary
- Two blocked**:** Both blocks of a tackle are as close together as they can be. Also refered to as block and block.
- Overhaul: Lengthen a tackle by pulling two blocks apart
- Round in: Bring the blocks of a tackle toward each other, usually without a load on the tackle

Blocks are constructed for use with fiber line or wire rope. Wire rope blocks are heavily constructed and have large sheaves with deep grooves. Fiber line blocks are generally not as heavily constructed and have smaller sheaves with shallow, wide grooves. A wire rope requires a large sheave to prevent sharp bending. Fiber line is flexible and pliable, so it doesn't need sheaves as large as those required for wire rope of the same size.

Blocks fitted with one, two, three, or four sheaves are often referred to as a single, double, triple, or quadruple block. Blocks are fitted with a number of attachments, such as hooks, shackles, eyes, and rings.

### 7.1.1 Block to Line Ratio

The size of a fiber line block is designated by the length in inches of the shell or cheek. The size of a standard wire rope block is controlled by the diameter of the rope. With nonstandard and special-purpose wire rope blocks, the size is found by measuring the diameter of one of its sheaves in inches.

Use care in selecting the proper size line or wire for the block you are using. If a fiber line is reeved onto a tackle that has sheaves below a certain minimum diameter, the line becomes distorted, which causes unnecessary wear. A wire rope too large for a sheave tends to pinch and damage the sheave. Also, the wire suffers damage because the radius of the bend is too short. A wire rope too small for a sheave lacks the necessary bearing surface, putting strain on only a few strands and shortening the life of the wire.

With fiber line, the length of the block used should be about three times the circumference of the line. However, an inch or so either way does not matter too much; for example, a 3 inch line maybe reeved onto an 8 inch block with no ill effects. As a rule, you are more likely to know the block size than the sheave diameter. However, the sheave diameter should be about twice the size of the circumference of the line used.

Wire rope manufacturers issue tables that give the proper sheave diameters used with the various types and sizes of wire rope they manufacture. In the absence of these, a rough rule of thumb is that the sheave diameter should be about 20 times the diameter of the wire. Remember with wire rope, it is the diameter, rather than circumference, and this rule refers to the diameter of the sheave, rather than to the size of the block, as with line.

### 7.1.2 Block Safety

Always consider safety when using block and tackle:

- Stress safety when hoisting and moving heavy objects around personnel with block and tackle.
- Check block and sheave condition before using them on a job:
  - Ensure the blocks are properly greased.
  - Ensure that the line and sheave are the right size for the job.
- Avoid use of worn, chipped, or corrugated sheaves and drums. Sheaves and drums in such condition will injure the line. Find out whether there is enough mechanical advantage in the amount of blocks to make the load as easy to handle as possible.
- Refrain from using wire rope in sheaves and blocks designed for fiber line. Those sheaves and blocks are not strong enough, and the rope will not fit the sheave grooves. Additionally, refrain from using fiber line on sheaves and blocks built for wire rope.

## 7.2.0 Chain Hoists

Chain hoists provide a convenient and efficient method for hoisting by hand under specific circumstances. The chief advantages of chain hoists are that the load can remain stationary without requiring attention and one person can operate the hoist to raise loads weighing several tons. The slow lifting travel on a chain hoist permits small movements, accurate adjustment of height, and gentle handling of loads. Use a ratchet handle pull hoist for short, horizontal pulls on heavy objects. Chain hoists differ ideally in their mechanical advantage, depending upon their rated capacity.

Three general types of chain hoists for vertical operation are the spur gear hoist, the differential chain hoist, and the screw gear hoist.

The spur gear hoist (*Figure 22-47 View A*) is the most satisfactory for ordinary operations. This type of hoist (*Figure 22-47 View B*) is about 85 percent efficient. The differential chain hoist is only about 35 percent efficient and is satisfactory for occasional use and light loads. The screw gear hoist is about 50 percent efficient and is satisfactory where less frequent use of the hoist is required.


**Figure 22-47 — View A: Spur gear chain hoist; View B: Differential chain hoist.**

Chain hoists are usually stamped with their load capacities on the shell of the upper block. Chain hoists are constructed with their lower hook as the weakest part of the assembly. This is done as a precaution so that the lower hook is overloaded before the chain hoist is overloaded. The lower hook starts to spread under the load, indicating the approaching overload limit. Under ordinary circumstances the pull exerted on a chain hoist by one or two people will not overload the hoist.

Inspect chain hoists before each use. Any evidence of spreading of the hook or excessive wear requires hook replacement. Distorted chain links indicates that the chain hoist has been heavily overloaded and is probably unsafe for continued use. Under such conditions, condemn the chain hoist. Before using any permanently mounted chain hoists, ensure the annual certification is current.

## 7.3.0 Winches

Vehicular mounted winches and engine driven winches are sometimes used in conjunction with tackles for hoisting. When placing a power winch to operate hoisting equipment, consider two points:

- The angle with the ground that the hoist line makes at the drum of the hoist: This angle is sometimes referred to as the ground angle (*Figure 22-48*).
- The fleet angle of the hoisting line winding on the drum: The distance from the drum to the sheave is the controlling factor in the fleet angle.

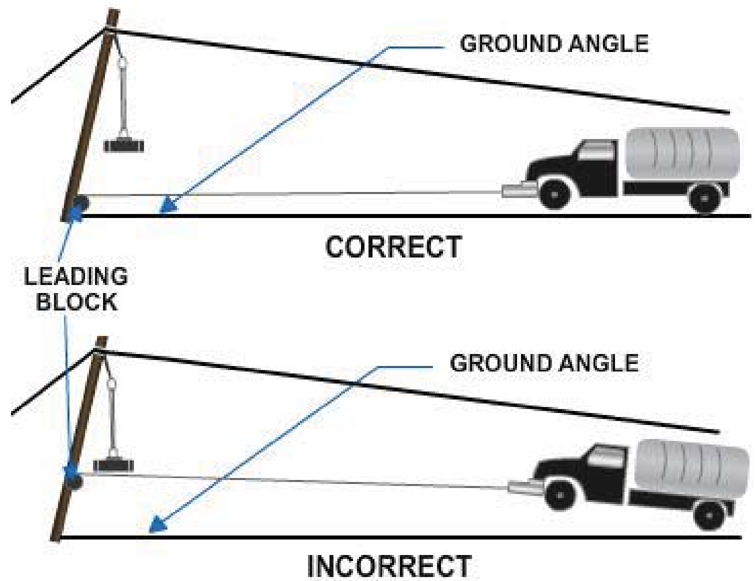



**Figure 22-48 — Vehicle winch used for hoisting.**

When using vehicle-mounted winches, place the vehicle in a position in which the operator can watch the load being hoisted. A winch is most effective when the pull is exerted on the bare drum of the winch. When a winch is rated at capacity, the rating applies only as the first layer of cable is wound onto the drum. The winch capacity reduces as each layer of cable is wound onto the drum because of the change in leverage resulting from the increased diameter of the drum. The capacity of the winch may decrease by as much as 50 percent when the last layer is being wound onto the drum.

### 7.3.1 Ground Angle

If the hoisting line leaves the drum at an angle upward from the ground, the resulting pull on the winch will tend to lift it off the ground. In such cases, place a leading block in the system at some distance from the drum to change the direction of the hoisting line to a horizontal or downward pull. The hoisting line should be overwound or underwound on the drum as may be necessary to avoid a reverse bend.

### 7.3.2 Fleet Angle

The drum of the winch is placed so that a line from the last block passing through the center of the drum is at right angles to the axis of the drum. The angle between this line and the hoisting line as it winds on the drum is called the fleet angle. As the hoisting line is wound in on the drum, it moves from one flange to the other, so the fleet angle changes during the hoisting process. Do not permit the fleet angle to exceed two degrees keep it below this, if possible. A 1.5 degree maximum angle is satisfactory and is obtained if the distance from the drum to the first sheave is 40 inches for each inch from the center of the drum flange. The wider the drum of the hoist, the greater the lead distance must be in placing the winch.

## Test your Knowledge (Select the Correct Response)

9. What term is used to describe an assembly of blocks and lines used to gain a mechanical advantage in lifting and pulling?

   A. Two blocked
   B. Tackle
   C. Overhaul
   D. Breech

10. With fiber line, the length of the block used should be approximately what size compared to the line?

    A. Three times the circumference of the line
    B. Four times the circumference of the line
    C. Five times the circumference of the line
    D. Six times the circumference of the line

11. Which of the following chain hoists has an efficiency of 85 percent?

    A. Screw gear
    B. Differential chain
    C. Spur gear
    D. Spindle gear

# 8.0.0 SAFE RIGGING OPERATIONS

All personnel involved in the use of rigging gear must be thoroughly instructed and trained to comply with several safety practices:

- Do not use wire rope with loads that exceed the rate capacity outlined in NAVFAC P-307. Use slings not included in that publication ONLY according to the manufacturer's recommendation or OME documentation.
- Determine the weight of a load before attempting any lift.
- Use the proper hitch.
- Guide loads with a tag line when practical.
- When using multiple leg slings, select the longest sling practical to reduce the stress on the individual sling legs.
- Attach the sling securely to the load.
- Pad or protect any sharp corners or edges with which the sling may come in contact to prevent chaffing.
- Keep the slings free of kinks, loops, and/or twists.
- Keep hands and fingers away from the area between the sling and the load.
- Start lifts slowly to avoid placing shock on the slings.
- Keep slings well lubricated to prevent corrosion.
- Do not pull the slings from under a load when the load is resting on the slings. Block the load up to remove the slings.

- Do not shorten a sling by knotting or using wire rope clips.
- Do not inspect wire rope slings by passing bare hands over the rope. Broken wires, if present, may cause serious injuries. When practical, wear leather palmed gloves when working with wire rope slings.
- Be mindful of the center of balance. Load stability is critical to the loading process. A stable load is one that has a center of balance directly below the hook. When a load is suspended, it will always shift to that position below the hook. To rig a stable load, establish the center of balance. Once center of balance is established, swing the hook over the center and select the length of sling needed from the hook to the lifting point of the load.
- When using a multi-legged bridle sling, do not assume that a three or four-leg hitch will safely lift a load equal to the safe load on one leg multiplied by the number of legs. With a four-legged bridle sling lifting a rigid load, it is possible for two of the legs to support practically the full load while the other two only balance it.

**NOTE**

If not all the legs of a multi-legged sling are required, secure the remaining legs out of the way.

## Test Your Knowledge (Select the Correct Response)

12. **(True or False)** To avoid placing shock on a set of slings, start a crane lift quickly and smoothly.

    A. True
    B. False

## Summary

In this topic you learned the basic concepts of rigging operations, basic rigging mathematical concepts, and the use of NAVFAC P-307.

You learned the distinctions of wire rope, including grades, lay, and lay length characteristics. You were presented with the method used to measure wire rope, the circumstances under which wire ropes are prone to failure, and the proper handling and care procedures that maximize the lifetime of wire rope.

You were presented with information about fiber line, including the different varieties, what tasks are best suited for each variety, and how to handle and care for fiber line. You learned about chain grades, strength, and proper handling techniques.

A significant focus of this chapter was developing your understanding of sling use and equipment. You were presented with different types of slings, proper use techniques, as well as administrative aspects.

This chapter discussed the mechanical advantages available, chain hoists, and winches. Particular attention was devoted to formulas used to compute safe loading and lifting.

## Review Questions (Select the Correct Response)

1. Which of the following factors is NOT considered during the initial phase of any rigging operation?

   A. Equipment selection
   B. Method of connection
   C. Effects of motion
   D. Magnitude

2. Which of the following methods is NOT an acceptable method used for determing load weight?

   A. Load indicating device
   B. Supervisor evaluation
   C. Label plates
   D. Engineer evaluation

3. What is the formula used to generate the area of a square?

   A. $A=\frac{B\,x\,H}{2}$
   B. $A=\pi\,x\,R^2$
   C. $A=LxW$
   D. $A=BxH$

4. What is the formula used to generate the area of a square?

   A. $A=LxW$
   B. $A=\frac{B\,x\,H}{2}$
   C. $A=BxH$
   D. $A=\pi\,x\,R^2$

5. You need to calculate the weight of an object, you know the area of the object and the material the object is manufactured out of; what is the next value needed to determine the weight?

   A. Thickness of material
   B. Capacity of lifting hoist
   C. Radius of material
   D. Volume of material

6. What is the formula for the calculation of cylinder volume?

    A. $V = L\,x\,W\,x\,H$
    B. $V = \pi\,x\,R^2\,x\,H$
    C. $V = \frac{\pi}{R_2}$
    D. $V = R^2\,x\,\pi$

7. If you have a high center of gravity and the attachment points are below the center of gravity, what will most likely occur to the load being lifted?

    A. Center balanced
    B. Less likely to tip over
    C. More prone to tip over
    D. Load shift to left

8. What is another term used for sling?

    A. Clamp
    B. Hoist
    C. Strap
    D. Choker

9. When a sling is bent around a small diameter load, the pieces will stretch, what would happen to the capacity of the sling?

    A. Reduce
    B. Enlarge
    C. Stay the same

10. Which of the following publications provides inspection requirements for WHE?

    A. COMSECONDNCBINST 11200.11
    B. NAVFAC P-307
    C. NSTM Chapter 613
    D. NAVFAC P-300

11. (True or False) Section 14 of NAVFAC P-307 applies to rigging gear maintenance.

    A. True
    B. False

12. Which of the following is NOT a goal of a effective test and inspection program?

    A. Prevent personnel injury
    B. Remove unsafe equipment
    C. Maintain crane qualifications
    D. Identify sub-standard equipment

13. What is the minimum amount of time equipment shall withstand a load test?

A. 30 minutes
B. 20 minutes
C. 10 minutes
D. 2 minutes

14. **(True or False)** Not all rigging equipment has to be marked with rated load value to be eligible for use.

A. True
B. False

15. Which of the following strand constructions has alternating large and small wires that provide a combination of great flexibility with a strong resistance to abrasion?

A. Ordinary
B. Seale
C. Warrington
D. Filler

16. Each square inch of improved plow steel can withstand a strain that is within what range, in pounds, of pressure?

A. Between 100,000 and 140,000
B. Between 240,000 and 260,000
C. Between 300,000 and 340,000
D. Between 440,000 and 440,000

17. What type of wire rope damage starts with the formation of a loop?

A. Crush spots
B. Wear spots
C. Kinks
D. Broken wires

18. In wire rope rigging, the diameter of sheave should never be less than how many times the diameter of the wire rope?

A. 10
B. 20
C. 30
D. 40

19. Type II, Protective A lubricant comes in three grades, which grade would be used in temperatures of between 80°F and 110°F?

A. Grade A
B. Grade B
C. Grade C

20. What term is used to describe the technique of attaching a socket to a wire rope by pouring hot zinc around it?

A. Seizing
B. Speltering
C. Wedging
D. Swaging

21. Which of the following formulas is used to obtain the number of wire clips required for a wire rope?

A. 6 x wire rope diameter
B. 3 x wire rope diameter
C. 6 x wire rope diameter + 1
D. 3 x wire rope diameter + 1

22. Wire rope eyes with thimbles and wire rope clips can hold approximately what percentage of strength of a wire rope?

A. 60
B. 70
C. 80
D. 90

23. Which of the following pieces of equipment is used to connect hoisting devices to beams?

A. Beam clamp
B. Plate clamp
C. Eyebolt
D. Turnbuckle

24. How are large ropes identified?

A. Tag attached to bitter end
B. Water resistant marker inserted into center of one strand of rope
C. By verifying it on receipt documentation
D. Water resistant marker inserted into open end of line

25. Cable laid ropes consist of how many right plain laid ropes twised together?

A. 1
B. 2
C. 3
D. 4

26. The stretch limit of a natural fiber rope is what percentage of its original length?

A. 10
B. 20
C. 30
D. 40

27. What color indicates a loss of strength in a natural fiber rope?

A. Yellow
B. Chalk white
C. Black
D. Green

28. While inspecting synthetic fiber ropes, you notice a musty odor emitting from the rope. What does this indicate?

A. Strands are saturated with water.
B. Rope has been stored in a dark environment.
C. Strands are saturated in oil.
D. Rope has suffered from rot.

29. Which of the following alloy steel chain grades are currently in use with the Seabees?

A. 60
B. 70
C. 100
D. 120

30. Which one of the following is NOT a reason for rejection during a chain sling inspection?

A. Discoloration of hook
B. Stretched chain links
C. Weld splatter
D. Heat damage

31. How many different types of wire rope slings are there?

A. 1
B. 2
C. 3
D. 4

32. **(True or False)** With a four legged bridle sling lifting a rigid load, it is possible for two of the sling legs to support practically the full load while the other two legs only balance it.

A. True
B. False

33. Which of the following degree sling angles is considered extremely hazardous and must be avoided?

A. 55
B. 50
C. 45
D. 30

34. Which of the following is a reason for immediate removal of service of a sling inspection?

A. Three broken wires in two strands in one lay
B. Six randomly distributed broken wires in one rope lay
C. Six broken wires in one strand in one lay
D. Three randomly distributed broken wires in one rope lay

35. Which of the following postions establishes and maintains a card file system containing a record of each sling in a unit's inventory?

A. Crane crew supervisor
B. ROICC
C. Crew leader
D Safety chief

36. To which of the following parts of the block is the standing part of the line attached?

A. Sheave
B. Shallow
C. Cheeks
D. Becket

37. Which of the following terms is the process of bringing the blocks of a tackle toward each other?

A. Round in
B. Standing
C. Fall
D. Movable block

38. The capacity of a winch may be reduced by what percentage when the last layer of wire rope is being wound onto the winch drum?

A. 30
B. 40
C. 50
D. 60

39. **(True or False)** Knotting and use of wire clips is an appropriate method for shortening a sling.

A. True
B. False

## Trade Terms Introduced in this Chapter

| | |
|---|---|
| **Core** | Wire rope consists of strands of wire wrapped around a core. The wire rope core supports the strands laid around it. There are three types of core. |
| **Abrasion** | A scraped spot or area; the result of rubbing or abrading |
| **Corrosion** | The act or process of corroding; condition of being corroded |
| **Fleet angle** | The distance from the drum to the sheave is the controlling factor in the fleet angle. |
| **Non-preformed wire rope** | Wire rope that has strands or wires that are not shaped before fabrication. |
| **Preformed wire rope** | Wire rope that has strands or wires that are shaped to conform to the curvature of the finished rope before laying up. |
| **Strands** | Several pieces of wire are wrapped around a core that constitutes wire rope. These pieces of wire wrapped around the core are called the strands. |
| **Tensile strength** | The strength necessary to withstand a certain maximum load applied to the rope. It includes a reserve of strength measured in a so-called factor of safety. |
| **Wire** | Rope consisting of steel, iron, or other metal in various sizes. The number of wires to a strand varies, depending on the intended purpose of the rope. Wire rope is designated by the number of strands per rope and the number of wires per strand. |

## Additional Resources and References

This chapter is intended to present thorough resources for task training. The following reference works are suggested for further study. This is optional material for continued education rather than for task training.

*COMFIRSTNCDINST 11200.2,* Naval Construction Force (NCF) Equipment Management Instruction. 06 JAN 2006.

*NAVFAC P-307,* Management of Weight Handling Equipment. June 2006.

*Rigging Manual,* 1st ed., Construction Safety Association of Ontario, 74 Victoria Street, Toronto, Ontario, Canada, 1975.

ASME B 30.9

*ASME B30.20*

*Wire and Fiber Rope and Rigging,* Naval Ship's Technical Manual, NAVSEA S9086-UU-STM-000/CH-613, Chapter 613, Commander, Naval Sea System Command, Washington, DC, 1978.

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